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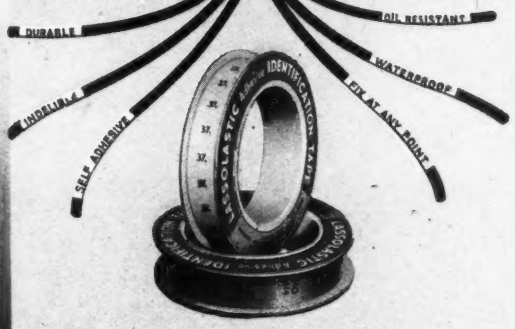

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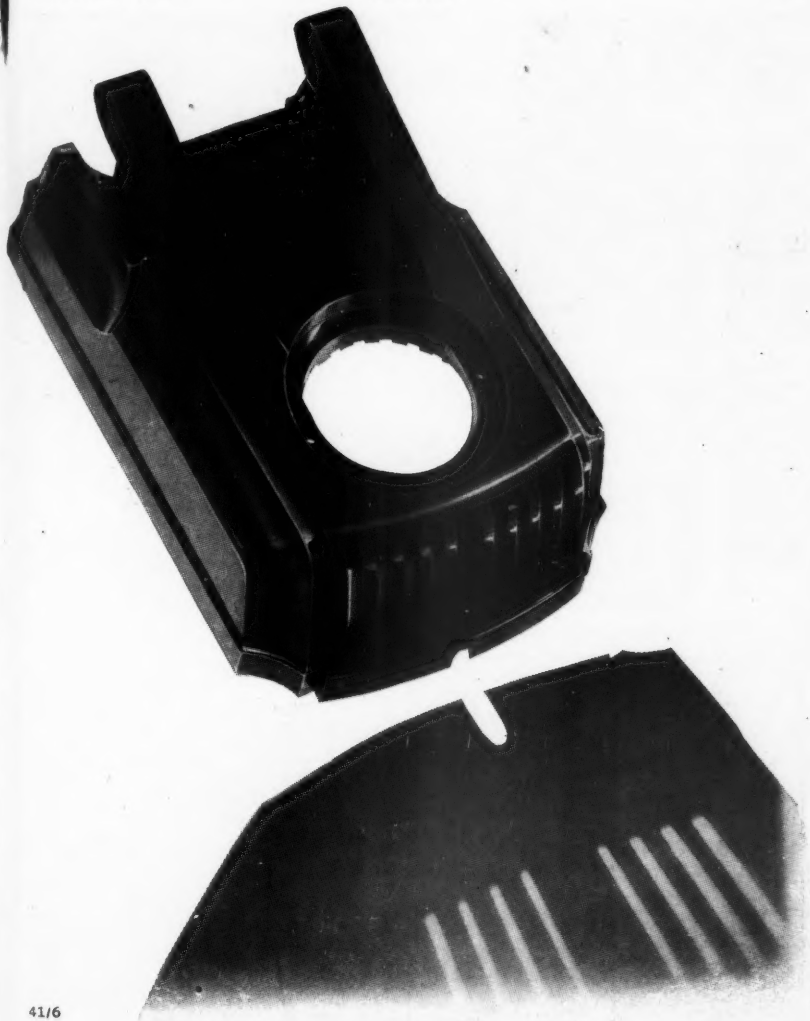

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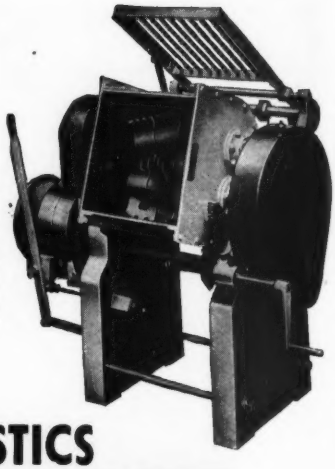

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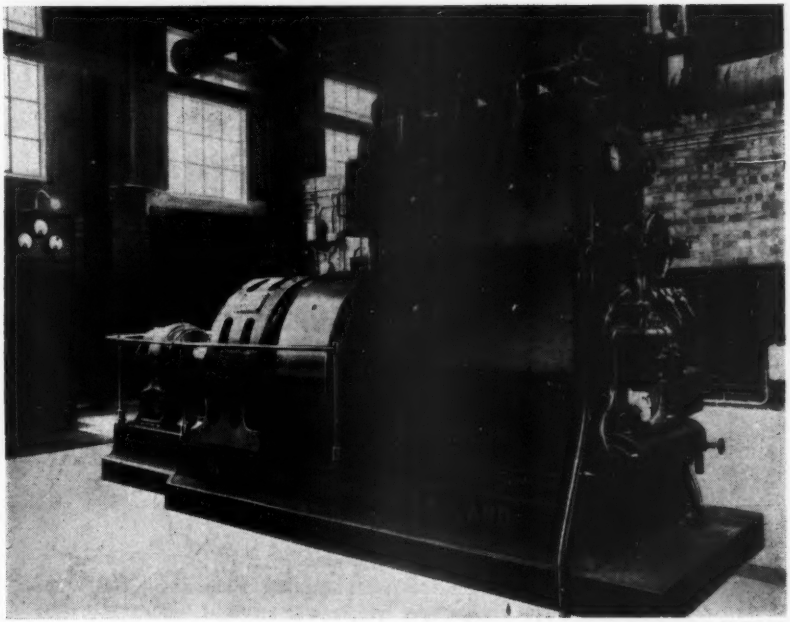

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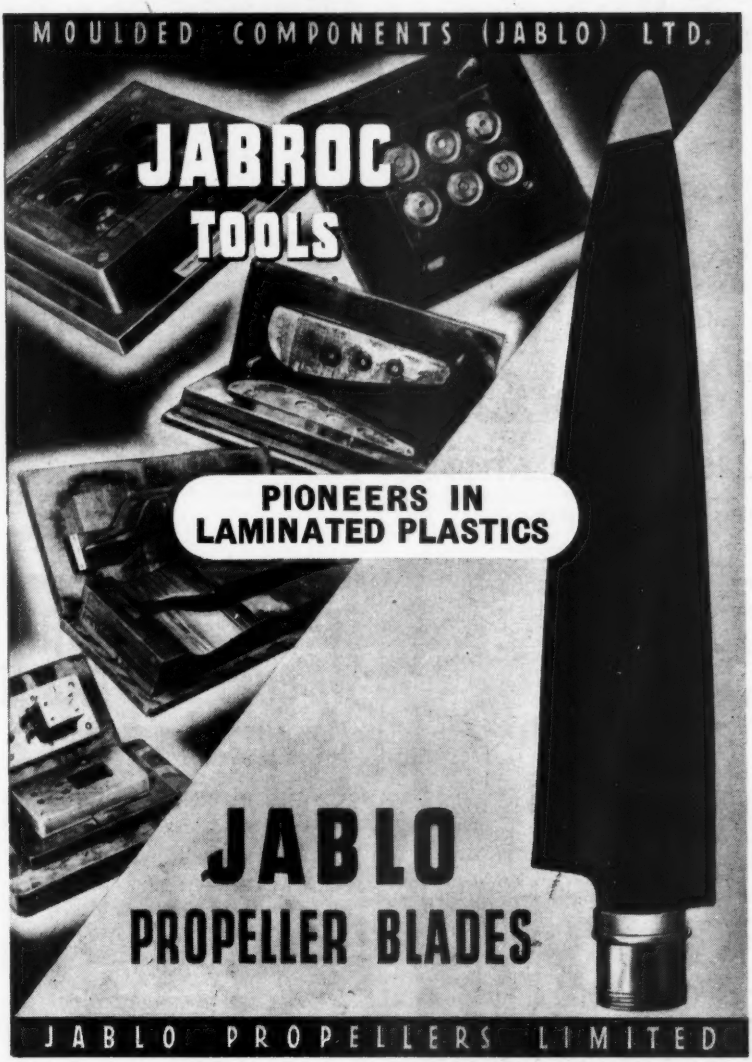
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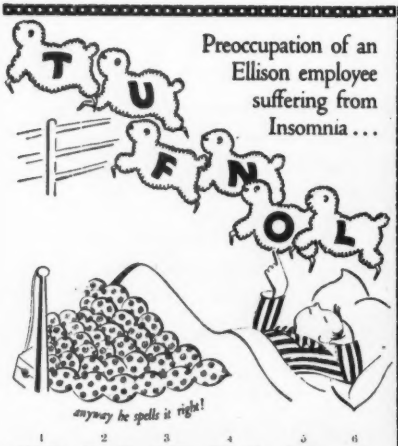

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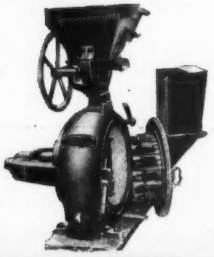

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VOL. VII. No. 69. JANUARY, 1943

Plastics

Dealing with the Manufacture, Uses and Potentialities of Plastic Materials

Proprietors - TEMPLE PRESS LIMITED
Managing Director ROLAND E. DANGERFIELD

Editor - M. D. CURWEN, B.Sc., A.I.C.
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IT seems strange, as everybody has already said to everyone else, that we can do in war-time in a few weeks or months things that take a hundred years to do in peace-time. A large number of examples comes to the mind, although it is the Beveridge plan that has fired the imagination of the country.

Perhaps of less immediate importance, but one which awakens the interest and hopes of every scientist in the country, is the recent announcement by Sir Evan Williams, the President of the British Coal Utilisation Research Association, that £1,000,000 has been provided as a fund from which £200,000 will be spent each year for five years to develop the uses of coal.

At long last, it has taken the greatest war of all time to convince the owners of the largest source of energy and probably of wealth of this country that it may be worth while finding out something about it. If we leave out the British Coal Utilisation Research Association because of its very recent formation, we have the situation that with an industry in their hands that takes in peace-time some 220,000,000 tons of coal out of the earth and worth annually, roughly, a similar number of pounds, not a penny has been spent by the coal owners during the past 100 or 200 years for any scientific and industrial research. Any research that has been done has been promoted by the users of coal, whether it has been for steam raising, producing benzol, dyestuffs, plastics, or general carbonization. "Not a penny" is, of course, an exaggeration, since we have some admirable examples in the Consett Iron Co., Staveley Coal and Iron Co., South Durham Steel and Iron Co., and a few others on the credit side.

Sir Evan Williams has described the plan as "The most important joint research project ever undertaken by an industry in any country for the development of a basic raw material." Without wishing to crab the new endeavour, which, indeed, is so welcome, this statement requires analysis. It probably is basically the biggest, but merely because the raw material is so common and because so many uses are made of it. From the proposed financial expenditure point of view, if this is taken into account, then £1,000,000 in five years seems a woefully small sum to spend on such vast problems. While statistics on the sums spent on research abroad are not before us, we do not doubt that even larger sums

have been spent on single problems such as the production of fuel oil by the Bergins process.

In the new scheme are included several interesting projects which hope to—

1. Increase the extractable energy in raw coal for domestic and industrial heating from the present 30 per cent.

2. Increase the number of by-products. including research on plastics, fuels and chemicals.

3. Develop new apparatus to increase the efficiency of coal burning.

To us, the fact that plastics are also " on the cards " is the most important feature, and we wonder how the line of attack will be approached and organized. Doubtless some liaison will be maintained with existing departments in the Department of Scientific and Industrial Research. We hope the scope and pocket of such an organization will be wide and deep.

The good gardener fertilizes freely.

Stories to Tell

READERS will have regretted that the Editor of this journal has not told the story of the contribution of the plastics industry to the war effort. Neither, of course, has any other journal, technical or non-technical.

The fault lies not in ourselves, dear readers, but in that double-locked, trebly-sealed volume known as the Secret List, which, so far as the plastics industry is concerned, is opened only to admit and never to pass out.

It is, therefore, to foreign literature, especially German, that we presume we must look to tell us about our own material. A good example is the British pilot seat described on p. 14 of this issue. It is a great pity that there is no organization which can give help to publicize the work of our industry in a manner analogous to that carried out in the sphere of aeronautics. Here the flow of information to the technical Press regarding new types of aircraft and units, as it leaves the Secret List, is unimpeded, and helps greatly in telling the world the story of British endeavour.

At some future date, we may yet tell of the mysterious No. 69, one of the best efforts in plastic moulding and still on the Secret List, although for the past year or two it has been known to every soldier, sailor, tinker, tailor and Nathaniel Gubbins. The Editor knows nothing. In fact, we have it on good authority that the idea was cribbed from the Italians, so we must not tell them about it lest they demand a commission on the sales.

Insulation and Plastics

IN the series of articles he has written for this journal under the general title of " Plastics in Assembled Building Structures," Mr. Fejér may not have given us hope for a great increase in the use of high-pressure moulded units for the building industry, but he has, by ingenious thought and design, pointed the way in which the resin-impregnated type of sheet structure may find important uses. In no small measure has he increased the interest of British architects in our industry.

He concludes his notes in this issue, after referring to the construction of insulating sheetings made of inorganic and other fibres, with the words: " The use of certain resins as binders is so obvious that it may be more than a guess that in another 10 years the majority of insulating structures will be resin bonded materials." A few hours before going to press with this issue we received a communication from Durez Plastics of New York State, which deals with this very subject. The Eagle-Picher Company of the U.S.A. has now introduced to the market a new type of insulating blanket made of " mineral wool," using Durez resin as a binder. It is claimed that the water-repellence of the resin enables the blanket to resist deterioration and to retain high thermal efficiency, despite long exposure to the humid conditions associated with low temperatures.

FOR THE CAR BODY

High Pressure Mouldings or Impregnated Plywood?

One of the most discussed problems in automotive circles since Ford made his first "plastic" car, has been the choice of raw materials as well as the methods of shaping them

By
D. Warburton Brown
A.M.I.A.E., M.I.P.I.

THERE has been a great deal of controversy on the subject of the use of plastics for the construction of automobile bodies, controversy which has come more into prominence since Ford actually produced a complete body from this type of material. The idea of a moulded body is undoubtedly attractive since a considerable reduction in weight could be achieved as well as the anti-drumming properties of the finished unit made possible by the high damping value of these materials.

There do seem to be several drawbacks to the plastic body when examined from a purely commercial standpoint. When considered in the light of mass-production requirements the total amount of raw material consumed would be very considerable and it is doubtful whether the raw-material producers could meet such a large additional demand upon their output, although they would doubtless be prepared to install new plant provided they were assured of increased sales. The present cost of the cheapest grade of phenolic material is approximately 1s. per lb., and the strongly reinforced materials such as would be necessary for body construction cost many times this figure. It is estimated that 155 lb. of plastic materials are used in the Ford body, and even assuming the lowest-priced grade of material to be used this represents a raw material cost of £7 15s. In addition to this Ford uses a tubular steel frame, and the raw material involved in its construction must be added to the cost of the plastics. In actual fact the higher cost of the reinforced material would increase this raw material charge some three times, bringing the cost of material only to an approximate total of nearly £25.

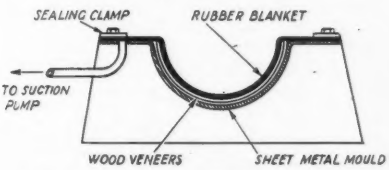


Fig. 1.—Principle of moulding wood-veneer material.

When it is remembered that in addition to this figure the cost of producing the moulded panels, and the overhead charges must be taken into consideration, and that the overheads on the large presses which would have to be utilized would be high, the total production cost of such a body would be excessive. An additional expenditure which would have to be borne is the outlay on large steel moulds. These tools would undoubtedly be expensive, and if the moulded plastic body were to compete on a price basis with the more conventional steel unit, multiple moulds would be essential, since the "cure" time for plastic panels, say, ¼ in. thick, would be in the region of 10-15 minutes.

Quite apart from the cost question, it is also necessary to take into account the press capacity which would be available. In order to produce panels of a size suitable for use on an automobile body, large

presses would be necessary, and at present there are certainly insufficient of these presses in the country to cater for the demands of the motor industry should the plastic body become an accomplished fact.

From the brief details given above, it will be seen that it is extremely doubtful whether the moulded plastics body will become a commercial proposition, and without a reorganization of both the raw material industry and the moulding industry the project would stand but little chance of reaching a production stage. It may be argued that it is unlikely that a man like Ford would agree to the carrying out of several years' development work on a plastic body, or to the expenditure on moulds and special presses and equipment, unless it had a very reasonable chance of meeting competitors on at least an equal footing. Ford, however, cannot be judged by ordinary standards. He has such a vast organization under his control that in the event of the plastic body being proved technically successful, it would not be at all surprising if he were to undertake the production of phenolic resin himself. As it is, he is utilizing by-products of farming to produce the reinforcing agent in his plastic panels. In addition, his market is so great that he can be content with small unit profits.

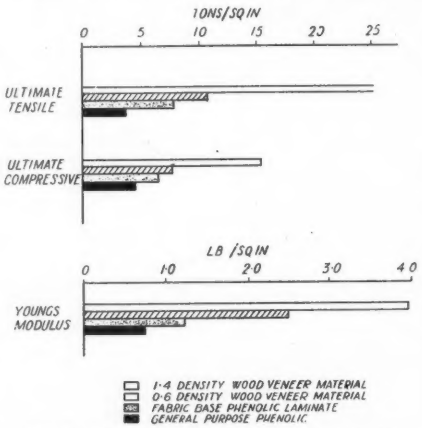


Fig. 2.—Comparison of mechanical properties of various plastics.

Although the use of the moulded plastics for car bodies seems to be extremely doubtful where the market is limited, another channel is open for the use of plastics in body construction. The use of plastic impregnated veneers and synthetic resin adhesives offers a possible method of producing bodies on an economic basis even though the market is not as vast as that open to Ford. The use of moulded plywood offers all the advantages of moulded plastics and many of the difficulties which accompany the use of the latter material disappear. The weight of plywood is even less than that of plastics, and the damping properties of this material are well known. It is very considerably stronger than the reinforced phenolic plastics, and the veneers can be arranged so that strength can be added at any point where it is required, for example, at points of anchorage.

Not only technical advantages, such as increased strength, are made possible by the use of moulded plywood, but there are very definite production and economic advantages to be gained by its use. No costly steel moulds are required and no large presses have to be employed. The cost of flat sheets of plywood indicate that the cost of raw materials for moulding would work out at a competitive figure. Tool costs are very small indeed, sheet-metal and wooden formers being used. The necessary heat and pressure for moulding the plywood are obtained by using autoclaves which are relatively easy and cheap to construct. A few notes will be given regarding the methods used for moulding so that the relatively simple nature of the process may be grasped.

As has already been pointed out, the moulds used for moulding plywood are made from polished sheet metal and wood. The shape to be moulded is formed in sheet metal which is supported on a

wooden framework. The impregnated veneers are laid into the sheet-metal form and a rubber blanket is fixed over them and securely clamped at the edges. The air from under the blanket is then exhausted by means of a vacuum pump, causing the veneers to be subjected to atmospheric pressure. This securely holds the impregnated veneers to the contours of the mould. The whole mould-assembly is then placed in an autoclave where it is subjected to steam pressure. Since the sheet metal is thin, the heat quickly penetrates to the veneers, and there is no pressure on the mould since it is acting equally pressure in the bag and that in the autoclave are raised simultaneously in order that no undue load shall be put on to the mould.

Laminated Wood and Plywood Material

Both laminated wood and plywood are built up from wood veneer material. In the former the grain in adjacent sheets runs parallel, whilst in the latter it is crossed to give strength in all directions. The wood veneers are available either impregnated or unimpregnated, and to date the latter type have been more widely used for moulded plywood, although

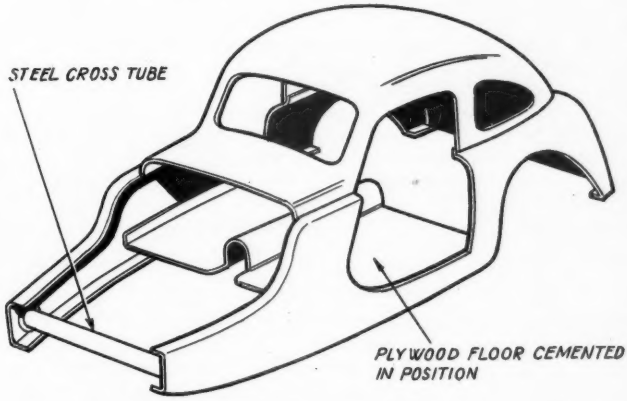


Fig. 3.—Monocoque body in moulded plywood.

all over the surfaces of the mould. The temperature and pressure required for the curing process are 300 degrees F. and 100 lb./sq. in. respectively, these values, of course, being average figures. It is estimated that the time required to cure completely plywood forms up to $\frac{3}{8}$ in. thick is between 10 and 15 minutes. With careful planning, however, it would be possible to arrange for several moulds to be stacked in the autoclave at the same time. The arrangement of the mould and veneers is shown diagrammatically in Fig. 1.

The arrangement shown in Fig. 1 is sometimes reversed, in so much that the rubber blanket is replaced by a rubber bag which is inflated by steam at the requisite temperature. In this case the there has been an increase in the use of the impregnated veneers in the past few years.

Unimpregnated veneers are generally bonded with a hot-setting thermosetting adhesive as this has been found to give the best durability and moisture resistance. Cold-setting adhesives are quite satisfactory for ordinary applications, but are slightly inferior under extreme conditions of heat and moisture. In general the use of hot-setting adhesives is advocated for panels and the cold-setting type for the production of heavier frames, etc. The use of cold-setting adhesives for frames is recommended because of the danger of damaging the wood by overheating when the hot-setting type is used, the cure time being proportional to the

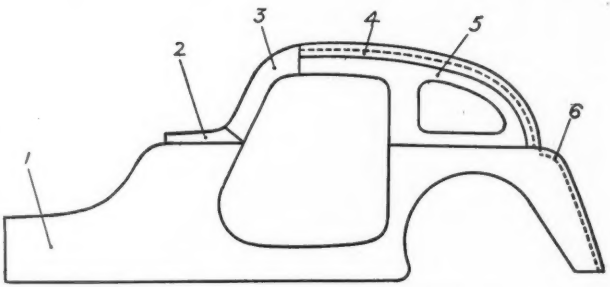


Fig. 4.—Subdivision of body into components: 1, main panels; 2, scuttle; 3, windscreen frame; 4, roof (can be subdivided further if necessary); 5, top side panels; 6, boot.

thickness of the member. The thermosetting adhesives which are now available are of the phenol-formaldehyde and urea-formaldehyde types, both of which can be obtained in the hot- and cold-setting varieties.

A certain amount of work has been done in the use of thermoplastic adhesives, especially in connection with the manufacture of propeller blanks, and the results have been good, but for moulded plywood structures there is still some investigation to be carried out in relation to the cold flow at gluelines. Cold flow is liable to occur even under low temperature and load conditions. When thermoplastic adhesives are used, therefore, the stresses and gluelines should be kept as low as possible. In this connection, however, it should be noted that this type of adhesive is used in the American "Vidal" process, and complete aircraft are flying which have been built by this method. The thermoplastics are generally based on the vinyl or cellulose groups of materials.

The potential uses of impregnated wood veneers have only comparatively recently been appreciated, and it is reasonable to assume that in the future this type of material will be much more widely used, since it is much stronger and tougher than the shock-resisting thermoplastics, even in the case of fabric-base laminates. A further advantage over the laminated plastics is the fact that wood veneer material can be moulded at substantially lower pressures. For example, the pressures required for laminated phenolics are in the region of 3 to 4 tons/sq. in., whereas 100 lb./sq. in. is all that is necessary to mould wood veneer material by the rubber bag and autoclave method.

Using spruce veneers as a basis, it is possible to produce laminated or plywood material with densities ranging from 0.6 to 1.5, the higher densities being produced in conventional presses. The physical properties of the material vary in almost direct proportion with the density. Wood veneer material having a density of 1.4 has been produced to give an ultimate tensile strength of as much as 23 tons/sq. in., the compressive strength and Young's Modulus being 16 tons/sq. in. and 4×10^6 lb./sq. in. respectively. The same

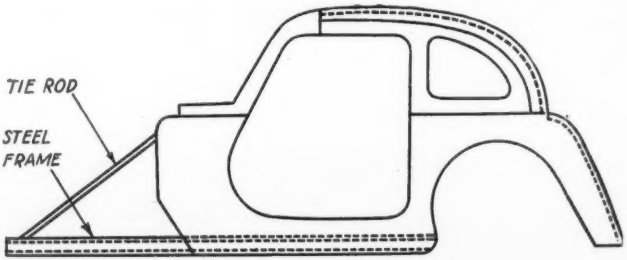


Fig. 5.—Moulded plywood body with steel frame floor.

values for laminated phenolic and general-purpose phenolic materials are given for comparison in Table 1 and shown graphically in Fig. 2.

Table 1.—Strength Comparisons between Wood Veneer and Plastic Materials.

Material	Sp. gr.	Ultimate tensile tons/sq. in.	Ult. compressive tons/sq. in.	Youngs mod. lb./sq. in. $\times 10^6$
General purpose phenolic woodflour filled ..	1.3	3.00	4.50	0.80
Fabric base phenolic laminate	1.34	8.00	8.00	1.20
Spruce veneer plywood..	1.4	23.00	16.00	4.00

Moisture Absorption of Wood Veneer Materials

In common with thermoplastic and thermosetting plastics, wood veneer material will absorb moisture from the atmosphere, but in the case of the latter material the degree of absorption is greater. The effect of moisture content upon unimpregnated wood veneers is a variation not only in dimensions, but also in strength. These effects can, however, be overcome to a large extent by the correct use of high-grade synthetic-resin finishes, and, providing these finishes are properly applied, they afford adequate protection to the wood for normal operating conditions, since the low permeability of the synthetic resin finishes prevents rapid changes in moisture content from occurring.

There is only limited data available on the effect of moisture on impregnated veneer material, but it is reasonable to assume that it will be similar to the case of the thermosetting plastics, since the effect of the resin will be to seal the wood fibres against the ingress of moisture.

Cost of Wood Veneer Materials

With regard to the cost of the wood-veneer type of materials, those using unimpregnated veneers can compete with metal even when the quantities involved are small, and since very considerable savings in tool costs can be effected there is an overall reduction in total expenditure. The question of tool costs assumes considerable importance in the case of automobile bodies, since the cost of press tools for a modern pressed-steel body may be as high as £75,000. It is estimated that the equipment required to produce moulded plywood bodies in quantities suitable for popular car manufacture would be well under half the former tool cost. This estimate includes the construction of suitable autoclaves as well as the ancillary equipment, such as moulds, etc.

There is, unfortunately, insufficient data available to give reliable information regarding the cost of the impregnated veneer material, but it would appear that in quantities of 600/700 the use of impregnated veneer material would be economic.

Limiting Factors

When formed or moulded wood veneer material is used, the size of the unit which can be produced is governed by the method of manufacture employed. If presses are used, as, for example, in the production of high-density material, the size of the unit is controlled by the size of mould which can be accommodated in the presses used, When one of the rubber-bag and autoclave methods is employed, however, the limitations of size are imposed solely by the dimensions of the autoclave.

In America autoclaves used in the manufacture of moulded plywood aircraft fuselages are some 8 ft. in diameter and as much as 35 ft. long. It is understood that larger equipment is in the course of construction.

Generally speaking, when using moulded wood veneer materials, the normal sheet-metal tolerances can be used, although the thickness of the material varies through wider limits. In this respect it is advisable to allow .030 in. on thicknesses up to and including $\frac{3}{16}$ in., and when the thickness is in the region of $\frac{1}{2}$ in. this tolerance should be doubled.

D

Wood veneer materials can be moulded in any thickness from 1-32 in. either by pressing or by the bag methods. When the material is to be used for applications where it is liable to be subjected to accidental impact loads it is recommended that the thickness of the material should be at least 3-32 in., although thinner material may be used for parts which are well protected from accidental impact. For the main panels of a car body it is

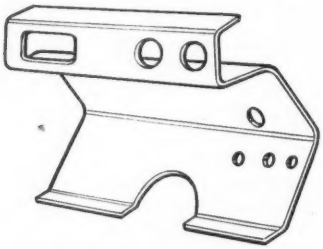


Fig. 6.—Combined dashboard and toe-board, to act as structural member.

recommended that the average thickness should be $\frac{1}{8}$ in.

When wood veneer material is used for exterior surfaces, such as the main structure of a car body, five-ply construction should be employed, the outer veneers being thinner than those in the centre. This eliminates the danger of surface cracks forming in the wood and the resulting failure of the surface finish.

Split Up of Body Components

When dealing with plastics as a medium for body building, it is necessary to split up the main body structure into various units of such size that each can be handled on the available presses. By using wood veneer materials this factor need not be taken into consideration because autoclaves can be made to accommodate the largest units likely to be used in automobile body construction. Nevertheless, from the point of view of veneer size and ease of handling, it is necessary to subdivide the main unit.

On the assumption that wood veneer material of approximately 0.7 density is used for the main shell of the body, a full monocoque or chassisless construction could be used, and Figs. 3 and 4 illustrate the general split up of such a body into convenient sub-units.

Referring to Figs. 3 and 4, it will be seen that the two main-load bearing members take the form of channel-section units extending the full length of the body. These, together with the other exterior panels, would be in $\frac{1}{8}$ in. thick plywood, which would be adequately strong to prevent damage through normal accidental impact loads. The remaining body sections, including the scuttle, windscreen frame, side panels, roof and boot, would all be cemented into position using a suitable type of synthetic resin adhesive, and the assembly would be carried out with specially designed clamping fixtures and drying chambers. At the same time, such ancillary units as the moulded floor, dash-

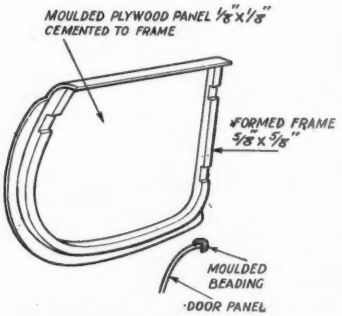


Fig. 7.—Door construction in moulded plywood and moulded resin.

board, rear-seat pan and wheel wells would also be cemented into position. The resulting box structure would be adequately strong to stand up to normal road usage, provided the various units such as the engine and gearbox were flexibly mounted on rubber supports. At the front end of the body a steel cross tube would be incorporated for the front engine and radiator mounting.

(Continued on p. 46)

Mechanism of Creep-path Formation

Detailing the Results of Laboratory Investigations into the Causes and Elimination of Electrical Leakage at the Surface of Organic Insulating Materials

UNDER unfavourable service conditions, there may be observed, even with high-quality plastics, the occurrence of creep currents, due to surface leakage. In low-tension electrical apparatus, which normally works perfectly satisfactorily, should this phenomenon occur, not only may apparatus itself be damaged, but surrounding equipment or structures may also be endangered.

In electrical engineering, creep of this type is defined as a current occurring at the surface, or in the uppermost layers of, a good insulator in a clean and dry condition, between parts of different potential.

The assumption here is that external factors acting on the surface of the insulator are primarily responsible, such factors being an accumulation of foreign matter or moisture. In general, from the practical standpoint, the formation and occurrence of creep currents may be neglected. From the physical standpoint, however, the phenomenon presents an interesting problem.

According to Vieweg and Klingelhoffer (Elektrotech. Zeitschrift, 1942/63/237), creep commences only after prolonged exposure of an insulator to service, and is to be attributed to the continued effect of electrical stress. For this reason, measurement of the periodic change of resistivity has been carried out.

Tests were made at elevated temperatures in order to facilitate more rapid determination of breakdown point, and, in the presence of high moisture contents in the surrounding atmosphere, in order to increase the intensity of the surface currents in relationship to the applied e.m.f.

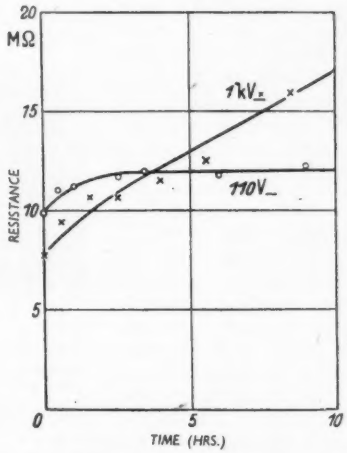


Fig. 1.—Curves showing the results of prolonged electrical stress on the insulating properties of a switch mounting (temperature 50 deg. C.; relative humidity 85 per cent.). Note that resistance of insulator has tended to increase.

Test pieces employed for such a purpose must be given some time to adapt themselves to the environment in which the test is to be carried out. Thus parts with gaps and internal cavities take some days to reach equilibrium. It is recommended that such test pieces be stored for a minimum of seven days before commencing investigations upon them.

The results of tests on a built-up switch are surprising (Fig. 1). Resistance increased continually in a most unexpected manner, and in no way do the curves obtained indicate that surface

breakdown may occur. This phenomenon may be explained by the fact that the heat caused by the current has the effect of drying out moisture occluded at the surface.

In recent literature it has frequently been assumed that a type of "electrical corrosion" may be responsible for the breakdown which sometimes occurs, and this theory has been supported by reference to visible structural changes.

Staeger produced photomicrographs of thin sections of plastics (loaded, for example, with sodium chloride), which, after some months, showed migration effects consequent upon the action of electrical currents. Segregation and structural changes of this type facilitate the recognition of the passages of currents. Nevertheless, a mechanism of this type presupposes that resistivity would *decrease*, but, in the case first cited, resistivity *increased*.

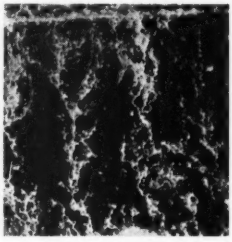


Fig. 2.—Filigree-like deposit on surface of plastic insulator caused by migration of metal from silver electrodes (magnified about 15 diams.).

As opposed to ionic migration in the plastic body itself however, surface migration of electrode materials must also be considered. This can be caused not only by the application of direct currents to the insulating body itself, but may also be caused by creep currents originating at the surface of the insulating material.

In Fig. 2 may be seen fine filigree-like tracks between two electrode surfaces of silver with a gap between. With an e.m.f. of 160 volts d.c. and with a sample of phenolic resin with woodflour filler, exposure to humid atmosphere containing ammonia caused this migration of silver particles to occur in three days. A point of unusual interest is the high resistance of this silver conducting path. A gap length of 1 cm. and width of 2 cm., as in Fig. 2, gave a resistance of 100 megohms. Such a resistance would appear to preclude the possibility of creep currents of any significant magnitude, or of harmful intensity, arising in this instance.

The laboratory production of conditions conducive to the formation of creep currents will now be described.

Effect of Arcing and Sparking

If an organic insulating material be frequently exposed to heat generated by the small arcs occurring in, say, low-voltage switches, charring or carbonization of the material may occur with a

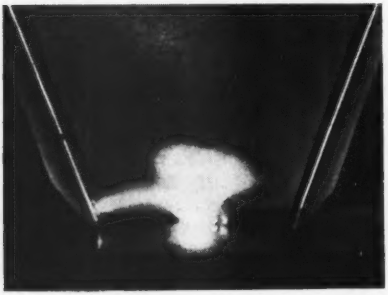


Fig. 3.—Spark discharge between knife-edge electrodes bearing on plastic surface. The spark is conducted, in part, by the charred surface adjacent to the right-hand electrode.

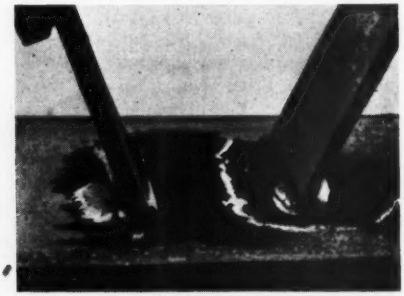


Fig. 4.—Knife-edge electrodes bearing on plastic surface and connected by high-resistance fluid creep path. Electrostatic forces have divided the fluid drop.

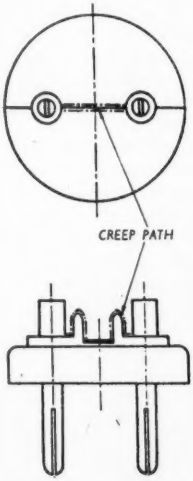
consequent production of a conducting surface. Resistance to creep currents arising in this way can be tested as follows:—Electrodes are suitably placed on the insulating surface to be tested and sparks are passed between them until a burnt path is produced, the carbonacious matter on which is itself a conductor.

Fig. 3 shows an arrangement in which knife-edge electrodes are connected with a spark coil. The apparatus was photographed when the spark discharged from one electrode has jumped to the charred matter on the insulator and so is conducted to the other electrode. A path for creep currents has thus obviously been created. Admittedly, in practice, conditions are less stringent, for in low-tension apparatus, air gaps are so arranged that spark discharge is not possible.

In cases where an insulating surface is covered with a fluid film, or with a dust layer (particularly metal-bearing dust), and where the risk of creep currents exists, the potential drop between the electrodes is not uniform. On a switch installed in a sooty atmosphere, bright metal parts carrying current soon become covered with conducting particles. The air gap between the contacts, sufficient in the case of clean apparatus to preclude any possibility of sparking or arcing, is now virtually reduced in that the e.m.f. present may be sufficient to cause a discharge between two or more soot grains in close proximity. If the first discharge taking place in this way causes burning of the plastic insulator, then a path for creep currents is already established.

For test purposes, simulation of conditions of this type is difficult, hence the use of weak conducting solutions is preferred. In practice, switches and plugs located on the walls of a damp room are subjected to conditions of this sort, and even careful installation and special apparatus in circumstances like this will not serve to prevent moisture condensing on the parts concerned. Where temperature variations occur, condensation can, in fact, take place even on fully enclosed apparatus; this may wash out sufficient conducting ions from the insulating material to initiate creep paths between conductors at different potentials.

The testing arrangement is shown in Fig. 4. Two knife-edge electrodes are placed on the plastic surface with an interval between them of 5 mm.; a drop of 1 per cent. aqueous sodium chloride



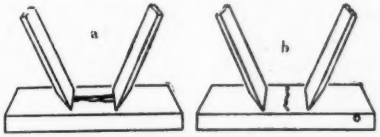


Fig. 5 (left).—Two designs for electric-light plug; the uppermost is unsatisfactory in that it presents possible path for creep, whilst that below is protected against failure by two massive ribs which tend to break any possible creep path.

Fig. 6 (above).—Test arrangements comprising two sets of knife-edge electrodes bearing on plastic surface. Between the set at the left a creep path has been established by charring due to sparking. Between the set at the right no permanent conducting path has been formed.

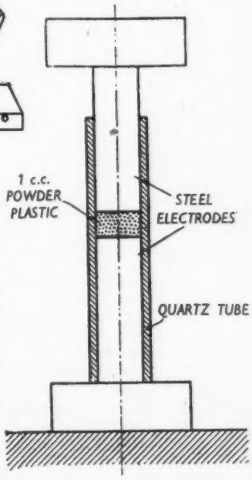


Fig. 7 (right).—Apparatus for measuring resistance at elevated temperatures of ash from organic insulators.

with a suitable wetting agent is now run on to establish a high-resistance path. As a result of electrostatic forces, the liquid drop becomes constricted in its centre, and, finally, divides, leaving a thin dry gap. If sparking occurs over this gap, heating of the plastic surface will result and, if this leads to charring, the surface

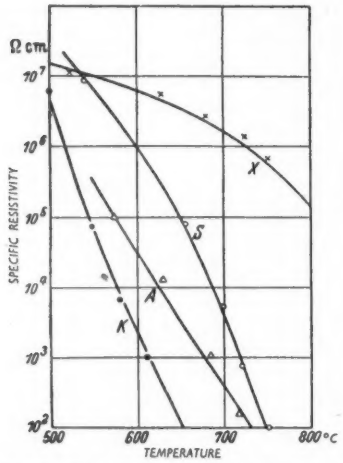


Fig. 8.—Resistance of various types of ash as determined by means of apparatus in Fig. 7: X, waterglass cement with asbestos filler; S, phenolic resin with woodflour filler; K, urea-formaldehyde resin; A, aniline-formaldehyde resin.

will become conducting and a permanent path for creep currents is formed.

The effect of electrical stresses at the gap is continually to enlarge the width of the latter with simultaneous heating and decomposition of the plastic surface until eventually a true creep path is established from one electrode to the other. This process, according to the degree of sparking occurring, may take as short a time as a few tenths of a second. Ultimate destruction of the insulator may be produced by a heavy short circuit.

Admittedly, the establishing of creep current conditions in this way is not likely to occur so readily in practice. However, it does indicate that the best protection to take in such circumstances is to provide against deposition of fluid by the use of enclosed switches, contact breakers, etc., and so to maintain the insulating surface upon which contacts are mounted in a dry condition.

The thermal properties of plastics are such that when atmospheric conditions are particularly unfavourable, condensation is likely to occur even in enclosed apparatus subjected to temperature change. The most that can be done then is to ensure, first, that condensation does not find a resting place across contacts, and, secondly, that such condensation be drained off into some type of sump, or through some outlet, to a point where it can cause no danger.

By avoiding the occurrence of large masses of material at strategic points, it is sometimes possible to ensure that such points rapidly attain equilibrium with the atmosphere, and thus become less prone to collection of condensed water. Possible creep paths may be rendered more difficult by the provision of massive projecting ribs, as shown in Fig. 5. A device of this type will go far to eliminate the danger of short circuits.

A condition very desirable, but more difficult to attain, is that of providing a definitely water-repellent surface, so that,

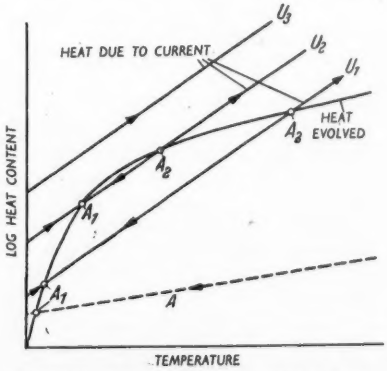


Fig. 9—Heat balance in creep path. Safety of the insulator, when once a creep path has been established, is largely governed by heat losses being of sufficient magnitude to maintain the resistance of the path at a high level.

should by chance moisture be deposited, it will tend to break up into isolated drops and immediately run off.

Incidentally, it may be noted that at least one American manufacturer has given attention to certain of these aspects and has designed control gear where, as far as possible, contracting surfaces are positioned vertically, thus guarding against deposition of foreign matter and conducting dusts in machine shops, and, at the same time, providing an opportunity for condensed moisture to run off. The test arrangement shown in Fig. 4, whatever may be its shortcomings, certainly allows distinction to be made between insulating materials which are proof against the generation of creep-current paths and those which are liable to become so affected.

If the surface of an insulating material becomes conductive as a result of charring or decomposition under the influence of a spark, sooner or later a permanently conducting path will be established between contacts or electrodes concerned (Fig. 6a).

If, however, after sparking, the insulator surface still remains a bad conductor, that is, if no significant decomposition occurs, and if the heat of the discharge drives off moisture, then it may be assumed that the condition will automatically cure itself and that the material is safe against the generation of paths for creep current (Fig. 6b).

It should be noted that different materials react differently to any given state of sparking or light-arcing conditions. For materials of high specific heat and high heat conductivity, temperature increase tends to be slow. Most organic insulating materials, however, do not possess these properties.

Of greater importance in the case of plastics is the temperature coefficient of resistivity of the combustion products, that is, in the case of plastics, the ash produced by surface charring. This will consist largely of carbonacious matter possessing a pronounced negative temperature coefficient at elevated temperatures, so that, in the neighbourhood of 7-800 degrees C. (which might readily be attained under the influence of a small arc or spark), the creep path becomes quite a good conductor.

A small furnace (Fig. 7) has been devised for measuring the resistance of ash of this type. It consists of a quartz tube to each end of which steel electrodes are fitted, the interval between them being packed with 1 c.c. of the plastic material in powder form. With this device, the curve shown in Fig. 8 has been obtained. Ceramic insulating

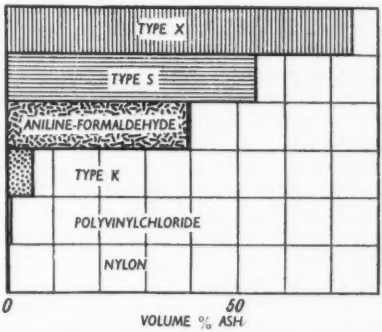


Fig. 10.—Ash contents of different plastics after heating for one hour at 800 deg. C. Type X (waterglass cement with asbestos filler) yields a non-conducting mineral ash. Nylon yields little carbonaceous matter.

materials or organic materials with inorganic fillers give only slightly inclined curves.

By means of the arrangement shown in Fig. 7, the thermal diagram as reproduced in Fig. 9 may be demonstrated to represent approximately the electrical condition occurring between conductors and along a creep path. The applied e.m.f. is assumed to be constant. With furnace temperature below 400 degrees C., the heating effect of the current might, under ideal conditions, cause the plastic powder to reach a temperature of 500 degrees C., but heat conductivity and radiation have been sufficient to keep the mass safely within the working temperature range. Where, however, furnace temperature exceeds a certain maximum, heat balance

is no longer possible, as heat generated by the current exceeds that lost by conduction radiation, etc.

The resistance curves for many organic insulating materials falls steeply under the conditions enumerated. Nevertheless, they may be demonstrated as remarkably safe against creep currents. The urea resin (k), for instance, gives a creep path interrupted by deep gaps which serve to break the continuity of the ash particles. This occurrence is to be attributed to the small volume of the ash as compared with that of the original plastic materials from which it was formed. Fig. 10 gives the ash contents for different plastics.

In the case of type S, ash remains coherent even when raised to incandescence, whilst in the case of material K (urea resin) considerable volume is lost by evaporation. Aniline-formaldehyde resins constitute an intermediate case as they give a pulverent ash lacking in the coherence exhibited by the fibrous ash of material type S.

Other phenomena can occur, tending to interrupt what might constitute a good conducting path. For example, in the case of nylon, the "burning" process takes place in an "explosive" manner, due to the generation of large volumes of gases, hence, breakdown of the ash-path is caused.

The general conclusions drawn from this research is that materials of type X (cement or waterglass with inorganic fillers) are practically proof against formation of creep paths. Materials, the ash volume of which is small or occurs in isolated masses, are also safe. In other cases, danger of the occurrence of creep paths can be reduced by the use of satisfactory designs of insulating surface.

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Pilot's Seat in Laminated Plastic*

Critical Commentary from a German Source on a British Innovation in Aircraft Construction

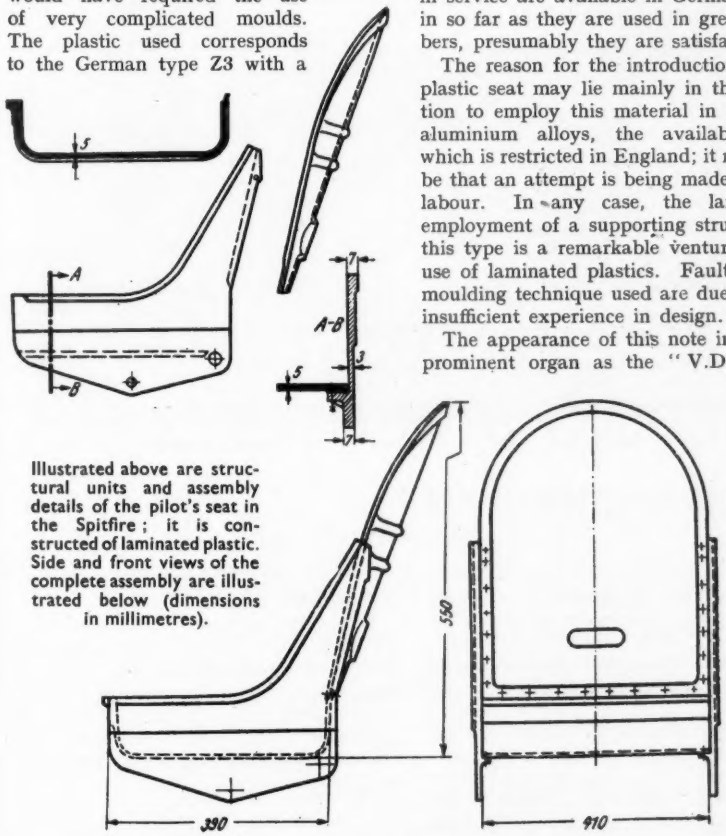
OCCASIONALLY, accounts and observations appearing in journals published outside Germany show that lightweight construction in plastics has been studied abroad with great attention, but developments of huge projected plants, more particularly those for aircraft construction, must be treated as suspect. Only with certainty can it be said that even before the war considerable activity was evident in the development of plastics of high strength for lighter structural purposes; these developments received the assistance and blessing of official bodies.

Far more definite information, however, is to be obtained in the form of plastic units or components retrieved from enemy aircraft which fall into German hands. These do not necessarily represent precisely the present state of technique, but certainly give a hint as to the trend of current development. An example of this type is to be seen in the application of laminated plastics for the pilot seat of the British fighter plane

* "V.D.I. Zeitschrift," 1942/86/398. "Luftwissen," 1942/9/17.

Spitfire. This unit combines the parachute seat cavity and a back rest.

The seat is not moulded in a single piece but consists of four parts joined by countersunk screws, a system dictated by reason of limitations of moulding technique, as such a moulding in a single unit would have required the use of very complicated moulds. The plastic used corresponds to the German type Z3 with a resin content of about 60 per cent. The quality of the moulded parts differs considerably in different examples of the pilot seat which have been recovered. Resin segregation and deformation in the laminations are frequently encountered, and, in general, can be traced to insufficient preparation and faulty laying of the paper sheets. Edgings and strengthening ribs are frequently produced in a manner not strictly in accordance with the known properties of the material being used. This probably leads to difficulties in mass production.



Illustrated above are structural units and assembly details of the pilot's seat in the Spitfire; it is constructed of laminated plastic. Side and front views of the complete assembly are illustrated below (dimensions in millimetres).

No data on the behaviour of these seats in service are available in Germany, but in so far as they are used in great numbers, presumably they are satisfactory.

The reason for the introduction of the plastic seat may lie mainly in the intention to employ this material in place of aluminium alloys, the availability of which is restricted in England; it may also be that an attempt is being made to save labour. In any case, the large-scale employment of a supporting structure of this type is a remarkable venture in the use of laminated plastics. Faults in the moulding technique used are due only to insufficient experience in design.

The appearance of this note in such a prominent organ as the "V.D.I. Zeitshrift" would appear to indicate that German industry is somewhat astonished by this new and logical development, and the reference to the adoption of plastics in place of aluminium, which we are told is in short supply in England, hardly ranks as a sound explanation for the adoption of the newer material.

E

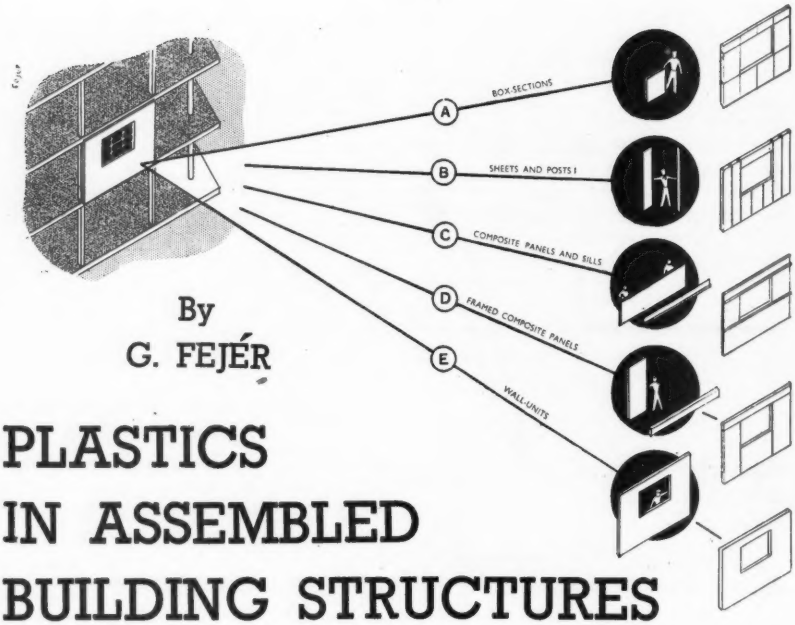


Fig. 1.—Five principles in wall construction.

By
G. FEJÉR

PLASTICS IN ASSEMBLED BUILDING STRUCTURES

III.—INSULATING WALLS

MANY of the uninitiated in the theory and practice of the manufacture of plastics appear to consider imminent the discovery of some remarkable (always inexpensive) plastic material which can be poured into moulds to form strong slabs and so can replace concrete without any of its disadvantages. That it will be possible to find such a resin or that it is even advisable to promote research along these lines is somewhat doubtful at the moment. There are other possibilities with existing materials, although the possibilities are not so simply conceived or carried out.

The outside walls of modern buildings present us with a number of new and intricate problems, which cannot be solved by making imitation bricks. Nor is the pre-casting of slabs (along the lines of reinforced concrete production) a necessarily suitable technique to be adopted for synthetic resins.

The numerous systems of making light insulating structures form a focal point for modern building science, and plastics already play a small, though not unimportant, part in the construction of such "dry-assembled" wall elements. We shall therefore concentrate on tabulating such structures only.

Stating the Problem

Whatever the type and character of the building, we can regard its walls as vertical, rigid structures, the primary function of which is to insulate against outside weather conditions. These need not necessarily be load-bearing structures, but they must be sufficiently rigid and self-supporting. Fig. 1 shows a visual interpretation of these conditions. Let us

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assume that the weight of the building is borne by a system of columns and rigid floors and the walls have a purely insulating function. Whether the columns are level with the wall front or set back from the frontage should not affect materially the performance of the wall itself. Let us assume, further, that the structural principle of wall construction is equally applicable to multi-storey buildings of different character, and not merely to a certain type or style of dwelling house.

On the right half of the illustration (Fig. 1) we can see five types of solutions to this problem, and, although many more are known, these prefabricating systems are probably the most interesting ones, indicating certain future uses of plastics and the possible direction of research.

It would be very difficult, if not impossible, to judge which type of solution is the most suitable for future building requirements. It may be regarded as an advantage to make the transportable units as large as transport and handling permit, because it is obvious that the larger the individual unit the less assembly has to be carried out on the site. A wall section of the type indicated under " E " offers less jointing and fewer sealing problems. On the other hand, it is equally true that the smaller the transportable units the fewer the variations needed, as a smaller component is more versatile in use. Box sections (see " A " on Fig. 1) which are approximately 1 sq. yd. in area can be used in a flexible manner, whilst wall units with an area of, say, 12 sq. yds. have to be produced especially to suit the architect's plan. Both principles are justified and sound, and it can be seen that the type of materials used, as well as production methods, have to be very different in both cases. Most prefabricators realize that their systems must be suitable for innumerable variations in architectural design, and that their main task is to devise systems rather than to mass produce houses of identical design. In fact, the five systems tabulated here are already suitable for a wide variety of designs. What should be the principal raw materials for such assembled walls? Metals, glass, wood, composite sheeting are being used to produce such heterogeneous structures, and there is no chance that any one raw material could entirely monopolize the field. The solutions are those combinations in which every material is used to its best advantage without preconceived ideas. There can be no finality as regards the choice of materials. Steady and simultaneous progress takes place as new sheet materials and insulating slabs become available.

Although there will be probably no such thing as a universal and ideal material ousting all others, the definition of an " ideal material " is useful in order to state the problems involved. According to American authorities,* the performance of an ideal material can be summarized under 10 points.

The ideal material for greatest efficiency in the building of houses should possess the following qualities:—

(1) It should be light in weight.

(2) It should be structurally strong.

(3) It should be durable.

(4) It should be fire resistant.

(5) It should be moisture, weather and sound proof, and should have a low rate of expansion.

(6) It should lend itself readily to moulding in large panels and sections.

(7). It should be easily bonded together to present either a smooth or broken finish.

(8). It should have permanent exterior and interior finishes in a variety of colours moulded into the units as integral parts of the material.

(9). It should be adaptable to assembly in either traditional or modern design.

(10). It should be inexpensive to produce in large quantities, and available throughout the country.

Whilst we cannot think of any of the available building materials fulfilling all these conditions, a reasonable solution to

*U.S. Temporary Economic Committee.

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the problem can be found by combining the available building products to achieve the optimum result.

Some of the Solutions

Let us consider five examples of prefabrication, which correspond to the five principles sketched in Fig. 1. The examples are related to systems developed at different dates (between 1920 and 1940) under different conditions, some in this country, others in the U.S., and are based on the characteristics of entirely different materials. The approach to these systems was very different in every case, and we shall comment on the wall-construction methods rather than on the merits of the buildings produced.

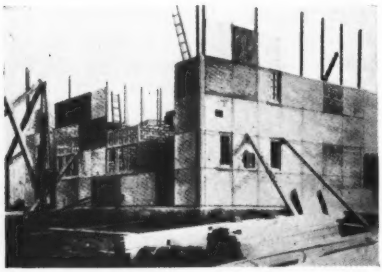


Fig. 2 (left).—The Thorncliffe system of wall structure.

Fig. 3 (below).—The G.B. (Pollard) method, utilizing wall sheets fixed in wood posts.

A. Box Sections.—There are various systems known in this country, on the Continent and in the U.S. which are based on the principle of box-like sections. Most of these systems have been developed during the past 10 years only, using pressed, stamped or rolled steel components, which can easily be assembled by bolting the flanges together.

The American prefabricating systems have been preceded, by many years, by a few British systems (1920-27), and Fig. 2 shows one of these early examples of workshop-made houses during erection. This system, the "Thorncliffe," provides walls made of cast-iron sections treated outside with asbestos or concrete compositions, and inside with a bituminous material to prevent corrosion. The interior wall surface is of sheet material, such as wallboard or similar alternatives. The essential feature of the system is certainly the shape and sizes of the transportable units. In spite of the vast changes in architecture and building science, this particular feature of the system is still up to date and in many respects superior to some of the more recent and wider-known types.

B. Posts and Sheet Material.—There are about 30 different systems which are based on the use of impervious sheet materials. Several American prefabricators have adopted the procedure of constructing the outside walls by using inside and outside sheeting on 2-in. by 4-in.

studs. The British "G.B." system (Fig. 3) falls into this category, although it has certain novel features. Concrete or wooden posts are being used on approximately 2-ft. centres suitably grooved to hold two asbestos cement sheets in position. The shape of the posts eliminates the use of nails, bolts or coverstrips. The space between the inside and outside sheet (about 4 ins.) is generally filled up with light insulating material. Although the insulation of the posts themselves must be less than that of the wall surfaces, the system as it is known now is used for war-time buildings only, and will probably be further improved to meet future requirements.

C. Sills and Composite Panels.—There are various systems developed by the John B. Pierce Foundation which suggest the use of horizontal sills and large horizontal panels. Fig. 4 shows the erection of a "Cemesto" house, the walls of which are designed on this principle. The panels are only about 1½ ins. thick, consisting of pre-finished asbestos cement sheeting on a multiple core of "Celotex" insulating boards. The panels, although fairly large (up to 4 ft. by 12 ft.), have no internal stiffening members or framing elements. Apart from a wide-spaced skeleton system the walls need very little support. The several hundreds of "Cemesto" houses erected in the past two years will offer valuable experience under practical living conditions.

Fig. 4.—The erection of a "Cemesto" house, using composite panels.

D. Framed Composite Panels.—Another approach to solve the problem of wall-panelling is based upon the fact that the vertical measurement is the main repetitive feature. Thus the height of the panels can be standardized in two or three sizes, without sacrificing anything of the freedom of architectural design, as far as dwellings are concerned.

The height of the sills is another vertical measurement which varies little. The "Uni-Seco" system (British) provides a wall structure which is assembled from units of standard heights. The widths of the under-window panels correspond to the standard metal-window sizes, and the full-height panels are available in a quite versatile and useful range of widths. Each panel is a framed, completely enclosed component with asbestos-cement faces, with a special type of insulation between. Fig. 5 illustrates the erection of a building of the hostel type. The system in its present stage already makes extensive use of the specific qualities of synthetic resins in the manufacture of the structural elements, such as eaves, columns and beams.

E. Wall Units.—We have already commented earlier in these pages on the wall-unit principle when dealing with transportable bathrooms (page 447 December issue). Most of these wall units are being assembled on jig tables, providing as much workshop finish as possible.

This principle is exemplified by the "Homosote" wall units, made from "Homosote" board. These are stated to be of chemically processed paper, in other words, a special type of hardboard.

"Homosote" and similar types of sheet material are generally used on approximately 2-in. by 4-in. studding, whilst resin-bonded plywood structures follow mostly the "stressed skin" principle of construction, which means that small sections (such as 1½-in. by 1½-in. frames and 1½-in. by ⅜-in. ribs) are being used in place of the more substantial studding.

The Essential Features

To sum up the alternative examples, which only represent a small fraction of the current systems, we can find that certain features recur in spite of the fact that we have to deal with systems of different origin and scope. The writer has omitted comparative detail sections of these systems partly because these would take up considerable space and partly because the detail solutions have been developed to suit the character of the materials, e.g., cast-iron, asbestos cement sheeting, etc.; these jointing and fixing details are subject to revision and improvements from time to time.

Whilst the choice of materials used and, subsequently, the details of jointing and assembly are subject to variations within the systems, considerations as to the shape and sizes of the transportable units remain relatively unaffected by the development of new materials.

Every one of the five methods can be regarded as a forerunner of future prefabricating systems, based on the same type of transportable units, although probably in different materials. As far as the details are concerned there is only one thing which recurs in all systems, and that is the use of impervious rigid sheeting for the outside and inside surfaces of the wall with cavities and low density insulating materials in between.

The framing or stiffening members vary according to the shape, size and stiffness of the sheeting used, but if studs or light framing members are necessary they can be regarded as sub-structural elements; we shall give, therefore, more detailed consideration of the possibilities of the manufacture of plastics for the following uses:

1. Rigid sheeting (flat or shaped).
2. Insulating materials.
3. Sub-structural framing members.

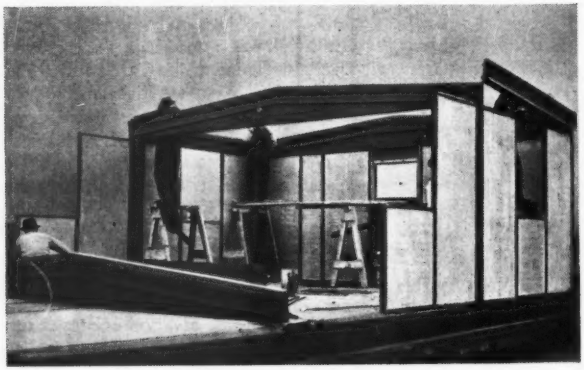


Fig. 5.—The "Uni-Seco" system. The wall units are erected, 4-in. fixing screws are inserted through the beam mortices and eaves-pieces are placed in position.

Plastics

When examining the 10 points for an "ideal" material already quoted, one cannot help feeling that most of the popular plastics are already fulfilling some of the 10 requirements, and it is also probable that points No. 6 and No. 8 have been drafted under their influence. Plastics

could play a very important part in the manufacture of the desired sheeting, of insulation materials, as well as of substructural elements. On the other hand, we must realize that the extent of research which is being promoted towards this end is by no means adequate, and can hardly be compared with the vigorous development of other building materials. Whether new plastic building materials will be systematically developed is not of the first importance in relation to the present argument, which is mainly concerned with tabulating the possible uses of known synthetic resins and processes irrespective of whether this field will be explored or not.

1. Rigid Sheeting

The problem of utilizing plastic materials for rigid sheeting has been stated earlier on these pages (pages 93-97, April, 1942), and we have also dealt with some of the solutions in more detail which come under this category. (See Vertical Panels and Table Tops, page 406, Nov., 1942). There are at least 10-12 varieties of flat, compressed-laminated or cast-resin sheets which are mainly used for decorative purposes. As far as can be ascertained, there is no plastic board which has been developed for external use on buildings. Most of our modern synthetic resins are excellent binders, in many respects superior to the plaster or cement-type binders. To produce efficient boards, we shall only have to find the suitable fillers. Paper is obviously not the best possible filler, and there is no evidence of paper-based phenolic or urea boards or panels being suitable for external use, but it is quite likely that such boards could be incorporated in transportable wall sections as internal linings. As far as interior uses are concerned, the laminated phenolics are comparable and for certain purposes even superior to the usual hardboards.

Fig. 6 illustrates transportable partition-sections consisting of Bakelite sheeting on a special frame, with light-metal cover strips. This type of fixing, of course, is only meant for one specific purpose and for the average partitioning of dwellings quite different systems have to be developed.

As we have mentioned before, the main question in the production of weather-proof plastic boards rests with the research to be carried out with various fibrous fillers. Asbestos cement sheeting is an excellent building material and, as it can be seen from our examples, the use of this material is very important for prefabricated sections. The excellence of asbestos cement sheeting is probably more due to the asbestos fibres than to the cement as binder. Asbestos " blankets " impregnated and bonded with a suitable thermosetting resin would probably result in a fairly expensive building material, but it is certain that these combinations have not been sufficiently explored so far. Another promising line of research is the exploitation of various fabrics as fillers. Alkyd-impregnated fabric as the covering layer of large plywood panels has already proved to be very useful for prefabricated wall-sections. There is no such a thing as an ideal wall-finish yet, and especially there is little choice between the traditional material for an ideal workshop-finish. Fabric-resin combinations, as surfacing layers of lamin-

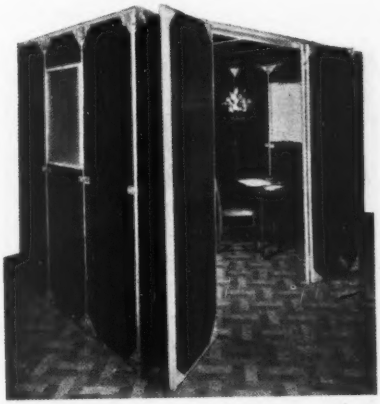


Fig. 6.—This structure of Bakelite panels in a metal frame was designed as an air conditioned room for tropical use.

ated sheets may, one day, bring us very near to an ideal solution, although there is a great deal of experimenting and testing necessary on the fabricating processes as well as the actual wearing qualities of such boards.

A beautiful example of the type of decorative board that can be produced from fabric resin combinations was shown on the I.C.I. stand at the British Industries Fair in 1937.

The fabricating possibilities of flat sheets or shaped panels with such finishes can be carried out in many different ways.

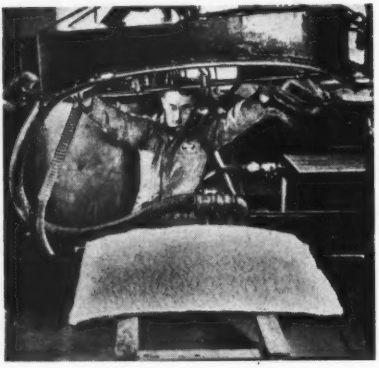


Fig. 7.—Ford's method of preforming motorcar panels.

Assuming that a thermo-hardening resin is being used for binding and "wetting" the fibres, the possibilities of carrying out the treatment are almost unlimited. It may not be necessary to apply high pressure, as it is not desirable to produce a dead flat, shiny surface, and the actual setting of the resin can be brought about by autoclaving, blowing dry heat, using certain accelerators, etc., or other similar methods well known to the industry.

What shape, thickness, and size of panel is the most desirable? It is certain that the usual specification of impervious sheeting is not the only solution, and, from the point of view of prefabrication, certainly not the best solution. As it can be seen from our examples, there is still scope for the usual stock-sizes in flat sheets, we have to note, however, that prefabrication has brought about two tendencies in the manufacture of sheeting: First, the manufacture of shaped (box-sections, pan-shaped sections, etc.) or otherwise stiffened sheets; secondly, the manufacture of flat sheets in larger sizes than hitherto. Both these tendencies originate from the aim to do away with cover strips, and awkward points of jointing, so far as is possible.

There is no reason why a laminated plastic board should be a narrow one, requiring a cover strip on every 2 ft. or 4 ft. By using continuous methods, the boards can be produced 8 ft. or 10 ft. wide and to any desired length, whilst, for the present, about 20 ft. appears to be the practical limit. Naturally for site-built partitions the narrower boards are handier. In the prefabricators' workshop the sheets can be fixed to the frame, which is not always practicable on the site.

The possibility of making plastic panels in the shape of box-sections has never been tested so far. Admittedly, such panels would not have a use as universal as sheeting, which can also be used for electrical and other engineering purposes. Panels which can be fixed along their invisible flanges could be made out of a number of well-known resins. To carry out the manufacture of such shapes need not necessarily require expensive moulds. The shaping arrangement used by Ford for the production of motorcar panels would certainly be capable of forming such building components. This arrangement (described on these pages, November, 1941) is stated to have two essential stages, i.e., the preforming, and compression with low pressure. Our Fig. 7 illustrates the first stage, when the preforming of the plastic mass is being carried out by using vacuum and a simple mould.

These possibilities are only a few of the most obvious approaches to produce plastic-sheeting and panels, for workshop-made wall-components. These, together with the earlier suggestions of the writer,

such as described in the May and April issues last year, may give an approximate idea of the possibilities which appear to be worthy of further investigation.

(2) Heat and Sound Insulating Materials

Whilst both faces of a prefabricated wall section must be firm, rigid, impervious and, therefore, exceedingly dense materials, the layer or layers forming the core of the components should be of low-density material with efficient thermal-insulating properties. There are three serious drawbacks which will occur in such composite wall structures if thermal insulation is not correct. First, there will be heating losses, causing loss of heating efficiency and wastage of fuel. The second and more noticeable drawback is that discolorations of the interior finish will show up every weak spot where the insulation is not efficient, as the dust particles and condensed moisture will be deposited on the cold spots of the wall surface to a greater extent than on the warmer, better-insulated surfaces. Thirdly, there is the condensation inside the structure itself. This can cause considerable trouble if there is not sufficient insulation between the surface layers. This last-mentioned difficulty cannot be avoided entirely by using insulating materials alone; it involves also careful design of the components, as it depends on a fairly complicated problem to balance the vapour pressures (outside, in the interior, and between the layers), to avoid accumulation of moisture inside the structure.

Fig. 8.—Onazote (expanded rubber) interlayer between veneers for the production of doors.

In prefabricated building of entirely " dry " construction, there is less moisture in the building to start with, and if we succeed in sealing the inside wall surface completely and provide sufficient thermal insulation there should be no condensation effects. The outside sheeting and joints must be watertight, but the former may be slightly porous, whilst the inside sheeting should be perfectly impervious. Much of the trouble of condensation is caused by using porous inside sheeting and impervious boards on the cold side.

In addition to the many older insulating materials there are also a few plastic products which could be used for insulating prefabricated wall sections. Let us recall only three examples mentioned previously in these pages. First, the rubber cellular material Onazote, which has been described in this journal (June, 1937). A panel veneered on both sides of an Onazote interlayer can be seen in Fig. 8. There is some evidence of experimental uses of acrylics and styrenes in such cellular forms. The second type of thermal-insulating plastic well known to readers is the lightweight insulating material called " Isoflex," one of the typical uses of which can be seen in Fig. 9. Isoflex is entirely composed of cellulose acetate material.

A third approach to an all-plastic insulating material lies with the use of pliable, extruded tubes, formed into a cellular mass. The experience gained in the manufacture of sponge and kapok substitutes could be utilized in the future for the production of thermal insulators. Whilst most of the thermoplastic resins

would be too expensive for such purposes, it is likely that moisture-proofed cellulose compositions could be made up into light insulating panels, at reasonable cost.

Resins as Binders Only.—The above examples of the approaches to plastic insulating materials refer to all-plastic products. The main basis of such materials as Isoflex or Onazote is the plastic used, although a small amount of modifying filler may be present. It is likely that all-plastic insulators will always remain lightweight materials, partly because of economic reasons, and will thus prove more suitable for vehicles, ships and aircraft than many of the usual insulating materials.

On the other hand, we have no indication as to the sound-absorbing qualities of these all-plastic insulators, and it is desirable that the thermal insulator used in the walls of buildings should, if possible, insulate against airborne or structure-borne noises. Extremely light materials cannot be regarded as efficient sound insulators for buildings, although capable of absorbing certain frequencies of airborne sound. So far as the building practice is concerned, there is a deep-rooted theory that an all-round sound insulator must be a heavy one, although this theory only holds within certain limits. Without going too deep into the fairly complex problems of sound insulation, we may conclude that an efficient insulating slab or quilt should be a low-density material with plenty of air chambers enclosed, but also sufficiently inert (on account of its weight and elasticity) to withstand vibration and membrane effects caused by sound.

To manufacture such insulating materials the qualities of modern resins as binders have never been systematically tried out so far. We have a number of cheap, non-plastic materials at our disposal which are capable of heat and sound insulation if suitably formed with binders. We mentioned glass silk earlier on these pages (November, 1942) as one of the fibrous materials which can be formed to make efficient insulators by using resin binders. Fibres and granules are capable of insulating against the transmission of heat and sound if suitably cemented to prevent setting and "tight packing." Also there are endless varieties of inorganic fibres and granules which could be utilized for the manufacture of insulating materials. The use of certain resins as binders is so obvious that it may be more than a guess that in another ten years' time the majority of insulating materials will be resin-bonded products.

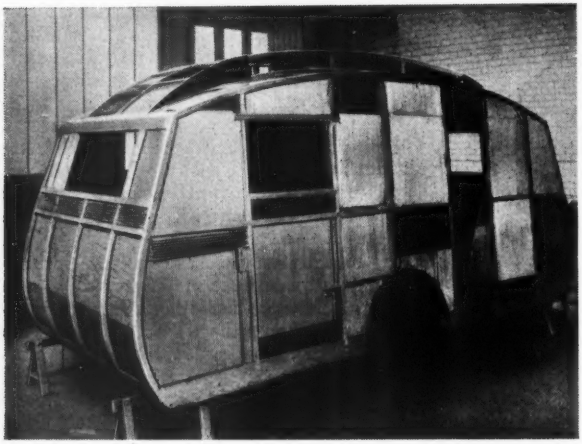
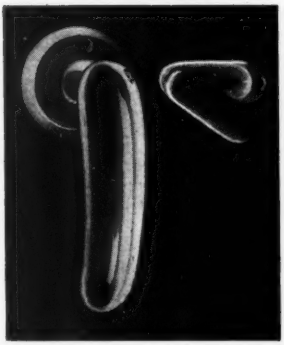


Fig. 9.—Isoflex sheets used to insulate a caravan (B.X. Plastics, Ltd.)

BUILDERS' FURNITURE —its design and production

The Rationale of Utilitarian Design in Plastics is Enunciated by a Leading German Technologist



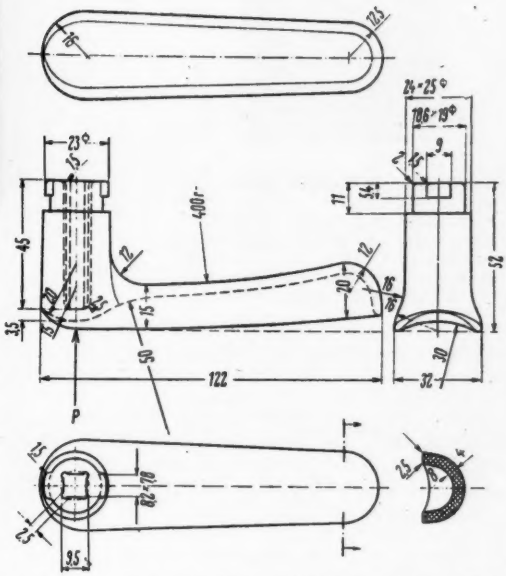


Fig. 1 (above).—Door handle, and escutcheon plate with cover, moulded from plastics. As opposed to earlier designs, the handle grip is hollowed in the front and not at the back; in this way, better handhold is provided. (The handle and escutcheon plate shown here are not in working position, but are reproduced as above for convenience). Fig. 2 (at right).—Detailed drawings and dimensions of the door handle shown in Fig. 1.

IN a recent account, H. Turnwald,* well known as a designer in plastics, describes new forms of door handles, door knobs, door shields and hooks, not only from the point of view of a practical design taking full advantage of plastic materials, but considering also the necessities of an economic moulding technique.

He refers to the fact that, until recently, the mould designer had to supply a suitable workpiece, based on the design submitted. In the future the designer of the component should be an engineer conversant with moulding technique. Only with an intimate knowledge of the production methods involved can he shape the components in such a way that they correspond to the technical and economic requirements of moulding practice.

The examples described will show that it is possible to create designs satisfying the demands of the moulding technique, and satisfactory from the æsthetic point of view.

In the case of the door handle (Figs. 1-2) the cavity is brought to the front, permitting a better grip. Further, when the door falls accidentally against a wall,

* Kunststoffe, 1942/32/17.

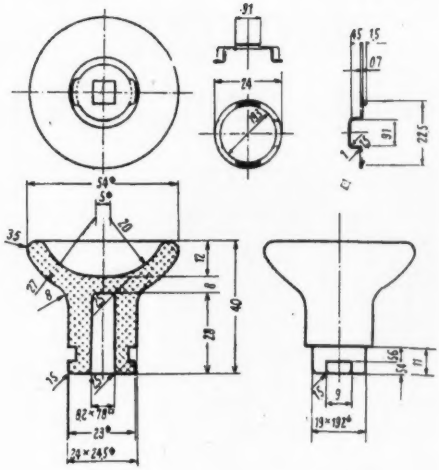


Fig. 3 (above).—Moulded door knob in plastics. Turnwald considers the knob form possesses technical and economic advantages as compared with the handle form (see Fig. 1). Fig. 4 (right). —Detailed drawings with dimensions of the knob shown in Fig. 3.

contact is made at a point near the axis; no bending momentum is present and the force P (see arrow in Fig. 2) acts directly on the metal insert. Differences in wall thickness occur only in the case of the square hole, but these are between normal limits, and do not impair the strength.

In the case of a highly stressed door handle, strength can be considerably increased by means of punched-out inserts of a laminated plastic with cellulose filler (Type Z3).

The round door knob has, hitherto, seldom been used on the Continent, whereas it is found almost universally in England and America. Turnwald states that it is practical and cheap, strong, and of good appearance. The translator cannot accept this view, and considers the true handle design more useful.

In the case of the round door knob, the cavity is placed towards the front, to obtain uniform wall thicknesses. The knob lies better in the hand, which improves both handling and appearance (Figs. 3-5).

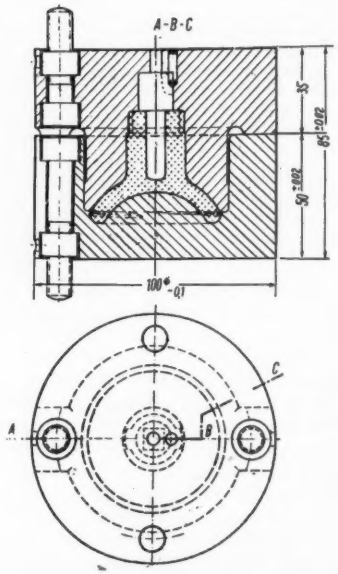


Fig. 5.—Design, construction and dimensions of the mould for the door knob illustrated in Fig. 3. It is suggested that the knob requires a mould of simpler form than that necessitated when producing a handle.

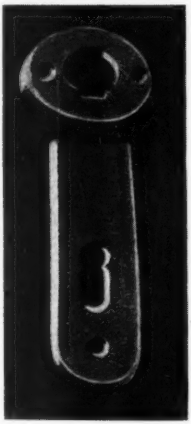
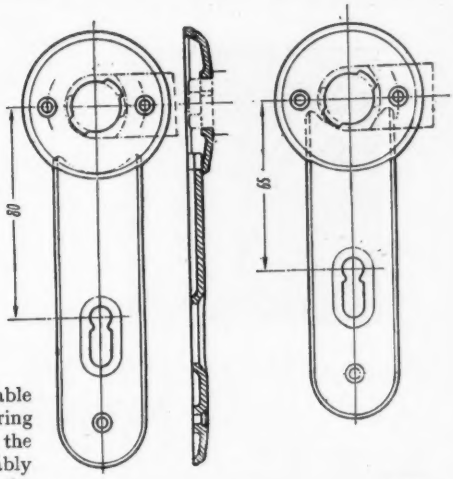


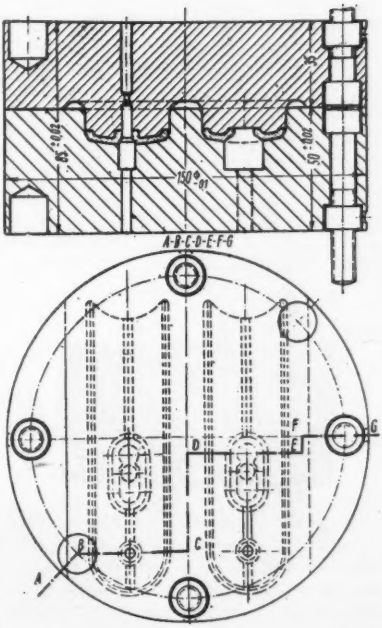
Fig. 6 (left).—Escutcheon plate with provision for adjustment to suit varying vertical positions of key-hole. Fig. 7 (below).—Detailed drawings of the escutcheon plate reproduced in Fig. 6, showing method of providing for vertical adjustment of key-hole position.



Connection in the case of non-rotatable door knobs is by means of a flat spring ring which is pressed in cavities of the lower part. The knob is preferably moulded (Fig. 5) with the cavity to the bottom. When the upper mould part is removed, the component is held in the lower mould part by an auxiliary thread. The threads of this screw are removed in the deburring operation. By these means, the ejector device, with its complications in mould construction, can be dispensed with. The mould in its outer dimensions corresponds to a unit system developed by Turnwald* and, therefore, can be used together with similar moulds on the same multiple mould, thus resulting in reduced costs.

Escutcheon Plate with Rosette

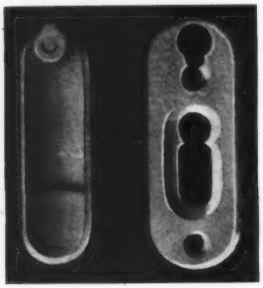
Fig. 6 shows an escutcheon plate in which the rosette can be adjusted length-



* H. Turnwald, "Das Normensystem im Pressformenbau," Frankfurt/Main, 1938.

Fig. 8 (right).—Unit mould according to Turnwald's system for the simultaneous production of the two components forming the escutcheon plate illustrated in Fig. 6. A moulding of practical design, but æsthetically satisfying, is, in this way, produced with minimum mould costs.

wise. For this purpose it has a cavity in which the plate can be adjusted by about $\frac{1}{8}$ in. (Fig. 7). The keyhole lies in a recess which considerably facilitates the introduction of the key. The plate is



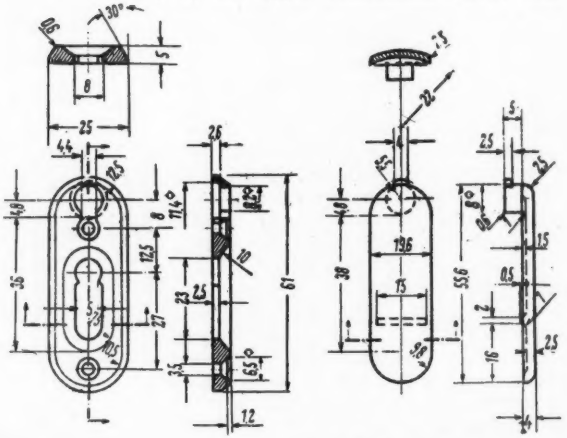


Fig. 9 (above).—Parts comprising moulded escutcheon plate with cover. Fig. 10 (below).—Escutcheon plate with inserted cover. Fig. 11 (right).—Details and dimensions of the escutcheon plates shown in Figs. 9 and 10.

slightly curved, to produce a better flowing of the plastic mass in the mould, this form also increasing the strength and preventing deformation during cooling of the component. It further ensures a flat position on the door. The boss for the hole has to project up to the supporting surface, however, in order that the tightening of the screw does not cause fracture. Two plates are moulded simultaneously in a unit mould.

Covered Escutcheon Plate

This apparently very simple and unimportant component is not quite so simple as a moulded part, if it be desired without any metal parts and if loose mould parts are to be avoided.

The result of these considerations was that the pivoted cover was moulded only by the two mould parts and is provided with a projection in the pivot, fitting into a corresponding recess of the plate. Removal of the cover is prevented only by the upper countersunk screw, with which the plate is fixed to the door. The head of this screw covers the groove in the pivot hole, so that the lid can be removed only after the removal of the screw and rotation through 180 degrees. Fig. 9 shows the recess and the pivot with projection, whilst Fig. 10 shows the plate with closed lid; the dimensions can be taken from Fig. 11.

The double mould for plate and cover is shown in Fig. 12. They are of unit design. Section C—F shows the formation of the projection at the pivot.

RUBBER INTO PLASTICS

Cups for collecting Latex from rubber trees have, of course, been made of many materials—cocoanut shells, metal, glass, earthenware. The interest in this new Latex cup, which is a very simple moulding in Beetle produced for The United Africa Company, Ltd., lies in the strange reversal of circumstances which have called in synthetic plastics to help production of one of the oldest of natural plastics.

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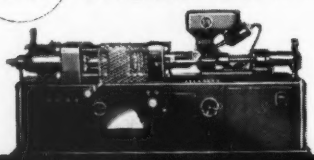

OUNCES OF MATERIAL PER SHOT 14½

MOULDING SIZE .. 14" x 7¾ x 4" deep

PRESS CYCLE ..... 1 minute

HORIZONTAL CLAMP
SINGLE INJECTION UNIT
Injection Capacities: 2 to 12 ounces per shot
Injection Pressure: 20,000 or 30,000 lbs.
Clamp Pressures: 40 - 100 - 200 & 350 tons
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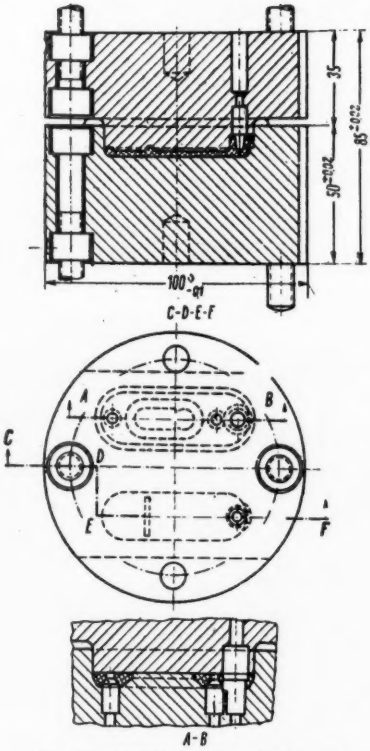


Fig. 12 (above).—Form, details and dimensions of the mould for the escutcheon plates shown in Figs. 9 and 10. Here again, for simplicity and economy, the unit method of mould construction has been adopted.

Clothes Hook

Before working out his own design, the author studied hook designs already on the market. This investigation showed that hooks were usually moulded on flat flash-type moulds with big flash edges. They show material accumulation at highly stressed points and are not very satisfactory from the point of view of moulding technique.

The new design attempts to avoid these faults by using, throughout, uniform wall thicknesses. The mould consists of single upper and lower halves only. Previous experience forbade the application of a flash-type mould, loose cores, slides, etc. The solution was to place the hook in an inclined position in the mould, as only in this way could the hook be easily extracted (Fig. 13).

Contrary to usual designs, the hook is attached by only a single central screw, as, according to the author, two screws do not always provide a straight fixing, and, in the event of a slight inclination, the hook is easily deformed by the load applied.

The upper hook serving for hats is of semi-spherical form, large enough to prevent heavier garments being placed on it instead of on the lower hook with shorter lever arm. The shape corre-

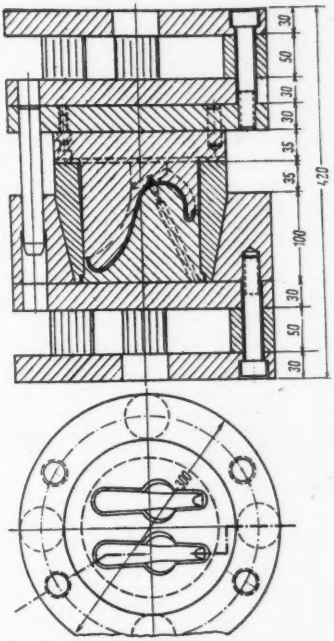


Fig. 13.—Details and dimensions of unit mould for the simultaneous production of two clothes hooks. The inclined position of the moulded product in the die is adopted to facilitate extraction.

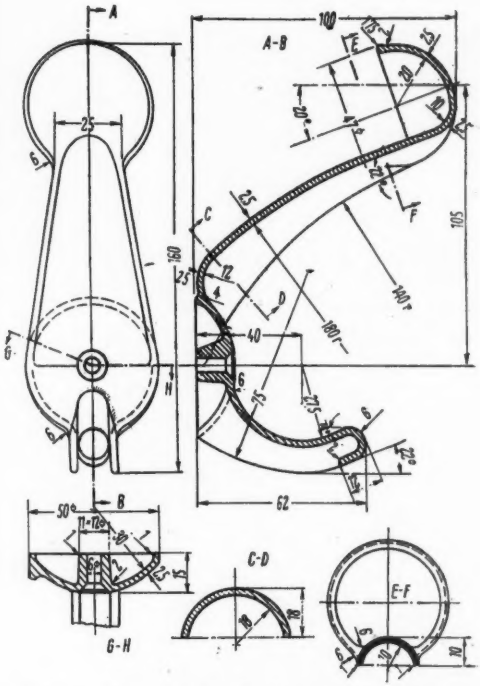
sponds to the requirements of moulding technique, possessing uniform wall-thickness and good curves giving unrestricted flow of material.

As the location and size of the curvature was selected according to the stresses encountered, an attractive and a very stable shape of high service durability was obtained. The price for this component is lower than that of other plastic hooks owing to the reduced moulding time and smaller material consumption.

The principles formulated and developed in this account are not claimed by Turnwald as entirely original; they are the logical outcome of a process of evolution in design taken over and turned to particular account by a technologist thoroughly conversant with the mechanical characteristics of plastics and the peculiar economic requirements of moulding technique.

It is to be noted that the progress attained has not resulted in the creation of any strikingly unusual forms, but rather in the maintenance of traditional types suitable for incorporation into current designs, with, however, just those necessary modifications required in order that the plastic article shall constitute a sound replacement for that previously projected in metal.

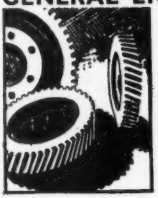
Fig. 14 (above).—Clothes hook to an attractive modern design, mechanically sound and well adapted to meet all the requirements of moulding technique. Attention is to be paid especially to the single point fixing. Fig. 15.—Detailed drawing of the clothes hook illustrated in Fig. 14. Note particularly the generous nature of the curves and sections used. The single hole fixing is designed to minimize danger of breaking when screwing into position.



(Note: Working drawings in this account are dimensioned throughout in millimetres.)

World's Industry Employs Plastics

GENERAL ENGINEERING



Equipment of machine shops for working vinedur and oppanal is dealt with by Klant in "Kunststoffe," 1942/32/307. It is pointed out that for economic use of these materials much special machinery is required. This is not needed where apparatus is being merely coated with plastics for protective purposes. For machinery, plant similar to that required for light metals and wood is suitable, viz., high-speed equipment. Plant need not be of intrinsically heavy construction owing to the low density of these plastics, but should be so located as to be capable of handling sheet up to 1-2 metres square and tubes up to 4 metres long. Circular and band saws with moderately coarse teeth and setting are necessary; too coarse setting, however, may cause splintering. Band saws 10-15 mm. wide and with tooth crests about 3 mm. apart are ideal. Circular saws should be fully adjustable for angular cutting, etc. Lathes with 30 cm. swing and 1 metre between centres are of a convenient size. For mass production, fully automatic plant is essential. Milling machines and pillar drills are necessary for economical carrying out of large orders. For hot forming a pneumatic press operating at 100 lb./sq. in. to give a total pressure of 5 tons on a platen 750 cm. by 75 cm. is required. Care should be taken in so working vinedur sheet that cooling of the material by the mould does not occur. Working is best carried out at 130 degrees C., heating being by means of an electrically warmed air blast or by means of a steam-heated oven. Ample room is required to allow operators to manipulate large sheets or tubes. **Bearings in plastic materials** are critically examined as to their application, and types of resin used, by Güttner ("Kunststoffe Techn.," 1942/12/43). Note is made of the different ways in which the synthetic resins may be adopted for the purpose—as uniform plastic masses consisting of resin and filler; as laminated plastics with wood, paper or textile lamination; and laminated-plastic linings on a metal basis. Large bearings built up from laminated-plastic sections are also referred to. **Excessive tool wear observed when machining certain thermosetting plastics** is commented upon by Jahn in "Kunststoffe," 1942/32/143. The responsibility for this is laid partly on the abrasive nature of the inorganic fillers used, and partly on the great hardness difference between the filler and the resin matrix (this producing all the effects of a continually interrupted cut). **Cutting tools of steatite,** prepared by a ceramics technique and developed by Osenberg, of Dresden, are claimed as suitable for overcoming this difficulty. Such tools are far superior to ordinary high-speed steel for use on plastics and possess an abnormal resistance to abrasion. Tools of all types may be made in this material either in the solid or with inserted cutters. Speeds, feeds and depth of cut are as recommended for carbide cutting tools. The use of massive boron carbide is also suggested. **Uses and limitations of natural rubber in machine construction** are examined by Brandown in "Maschenbau/Betrieb," 1941/20/77. The specifically superior properties of the synthetic rubbers commend their application for this purpose. The temperature range in which Buna S, Buna SS and Perbunan may safely be employed is such that it is able to withstand a load increase of 50 per cent. as compared with natural

rubber at maximum working temperature; at lowest working temperature, however, the load-carrying capacity of these synthetics is about 75 per cent. of that of natural rubber at the same temperature. **Wear of plastic toothed gears** was the subject of examination by Opitz and Reese, reported in " Kunststoffe," 1942/32/263. Gears of resin-impregnated laminated wood and textile laminates were employed, running in mesh with cast-iron wheels lubricated with grease. In the case of the wood laminate, veneers of thickness of 1.0 mm. gave the best results; thinner veneers, or increased resin impregnation, did not result in improved wear properties. Compression of the laminate during fabrication beyond 200 kg./cm.^{2} proved of no advantage, although below this figure variable results were obtained. Comparative tests on the wood and textile laminates disclosed no great differences between their wear-resisting properties. Wear increased with increase in running speed and load. The authors also consider the effects of tooth modulus and the number of teeth, and, on the basis of their work, formulate general recommendations for the design of plastic gears. **The strength of plastic gears** is the subject of research by Müller, reported in the same issue (p. 270). Bending strength for coarse textile laminates of 1338-1378 kg./cm.^{2} were obtained, the corresponding figures for fine laminates lying between 1554 and 1569 kg./cm.^{2} Compressed, impregnated laminated wood gave 1716-1878 kg./cm.^{2}

MISCELLANEOUS

Sausage skins produced from bleached wood cellulose are described by Weingand in " Gelatine, Leim, Klebstoffe," Vol. 9, p. 123. The cellulose is brought into solution by the viscose method, or by light nitration, and is then extruded in the seamless form, after which it is treated to regenerate the cellulose. Final treatment may be continuous, or in batches using up to 5 metres of sausage skin at a time. For special types of sausage, adhesion of the contents to the skin is prevented by coating the inner surface of the latter with a gelatine film. Skins of the types described are available in diameters 35-120 mm., with wall thicknesses of 0.03-0.08 mm., and capable of withstanding a bursting pressure of 1-2 kg./cm. A good sausage skin should be capable of supporting a column of water 2.5 metres in height. **Protection of spun-paper bindings and fastenings for packaging** against moisture and bacterial and fungus attack is considered by Dreper and Reichel in " Papierfabrikation," 1942/Nos. 7-8. Particular attention is directed to the type and quality of adhesives used. A phenolic-resin adhesive, Naviral PR, is recommended as a combined adhesive and fungicide. It is a viscous fluid, thinned for use with water. Subsequent heating of the work is required to harden the adhesive and to assure its maximum impermeability to moisture from outside or from the contents of the package. **Non-uniform flow of plastics during extrusion** is referred to by Unckel in " Zeit. Techn. Phys.," 1941/22/105. Experiments were carried out with wax and aluminium, the die openings being either eccentric to the cylinder bore or consisting of two or more orifices in the die head. The results obtained, it is said, can be directly applied to the interpretation of similar phenomena in synthetic-resin extrusion. **Anisotropic behaviour of laminated plastics with respect to thermal expansivity** is examined by Vieweg and Schneider in " Kunststoffe," 1942/32/295. The authors show that expansion and contraction under heat vary with direction of measurement through the mass. Coefficient of expansivity at right angles to the direction of lamination is higher than that for the direction parallel to the direction of lamination. Textile and paper laminates were examined and it was demonstrated conclusively that the classical approximate for volume expansion as 3 × linear expansion does not hold good.

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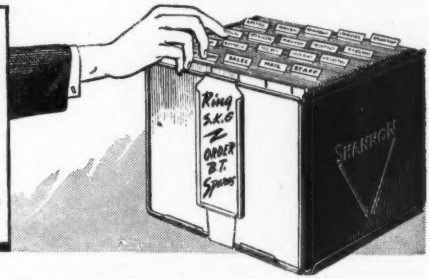

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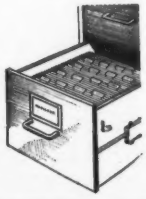

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INQUIRIES AND ANSWERS

(In Which is Included General Correspondence)

IMPORTANT NOTICE: If inquirers wish to receive replies by post, a stamped and addressed envelope must be included in their letter. Unless otherwise stipulated, it is understood that the submission of a problem to the Editor permits its publication in this journal.

Standardization of Plastics

Having read with great interest "Standardization of Plastics in Germany" ("Plastics," pages 442/3) and as one who some years ago took part in this standardization, I would like to add a few remarks which may be of interest to you.

The increase to 26 different standardized plastic materials is the result of the blockade which before the war was voluntarily imposed by the Germans on themselves to save foreign currency. For instance, since asbestos was no longer abundantly available, it was replaced in Type 12 by other mineral fillers. The introduction of the types Z 1-3 was made because of the shortage of textile fillers normally used in types T 1-3, Z being the first letter for Zellwolle or Zellstoff = cellulose. I regret that the thermal qualities were omitted in your table as these are always of great importance for the electrical designer. Further, I would like to point out that under "phenolic resin," according to the German definition, cresylic resins are included. For instance, the types "O" are definitely made from cresylic resins. With regard to the type "Y" there is only one material which complies with this specification; this is Mycalex, manufactured in Germany by the A.E.G., in Great Britain by the Mycalex Co., Ltd., and in U.S.A. by the G.E.C., Schenectady, as the original patent holders and licensees. The Americans seem to have made very much progress with this material, as you reported from "Modern Plastics" some time ago that they are already carrying out injection moulding with Mycalex. With regard to the types T3 and Z3, I would say that these are laminated mouldings, made in moulding tools. In Germany, specifications are issued by the V.D.E. for laminated sheet material, tubes and rods.

Finally, I would like to say that the values given in the table are minimum values with which the producer has to comply if he intends to use the special sign on his mouldings designating manufacture to specification. Every producer of such plastics uses, in addition to this sign, a number of his own. The values themselves are given only for prepared testing pieces cut off plates and do not give the real value which the plastics can stand, this value being very much dependent on the design of the plastic article.

W. CORNEHLI.

London, W.9.

Re Formvar Bond for Airscrews

I have read with great interest the article on page 425 of your December issue.

I thought your readers would like to know that thermoplastic resins were utilized by Messrs. Moulded Components (Jablo), Ltd., in the manufacture of rotor blades for helicopters in 1937.

These blades were of such a length that there were no presses available suitable for producing them in a single operation.

This fact led Messrs. Moulded Components to experiment with synthetic thermoplastic resins. These were found most suitable for the production of long blades in several over-lapping operations.

Moreover, it must be added that the adapter which is claimed as a new development of the Hordern-Richmond Company, is not new at all. It has been embodied in experimental die-moulded propellers by Messrs. Moulded Components (Jablo), Ltd., and is published and given in Patent Specification No. 493,145. Patent applied for in March, 1938, granted in September, 1938.

Furthermore, this particular type of

root fixing is more definitely covered by Patent Specification No. 489,400. Patent applied for in April, 1937, granted in July, 1938.

MOULDED COMPONENTS (JABLO), LTD.

Croydon.

Cellulose Bottles

In your December issue, page 453, mention was made of cistern swimmers constructed from cellulose nitrate sheet material blown with dry heat to the required shape.

I am wondering whether you can give me any idea as to the possibility of constructing one-piece bottles from transparent plastics, or, alternatively, the names of any manufacturers who might be prepared to consider this from a post-war viewpoint.

Any assistance you can give me in this direction will be much appreciated.

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Richmond.

EDITOR'S NOTE.—Bottles could readily be made by the injection process. In fact, we reported in our October, 1938, and February, 1939, issues that a London financial group had interested itself in the production of plastic milk bottles. Information was also circulated to the effect that Reed Prentice machines had been installed somewhere to produce 3,000,000 acetate bottles per annum. We have heard nothing since.

PROTECTION OF CONCRETE TANKS

The Value of Chlorinated Rubber

BECAUSE of their convenience, cheapness and flexibility of construction, concrete tanks are often used for storing not only water but also corrosive and other solutions that are apt to have a deleterious effect on structural materials. Typical in the chemical and allied industries, as well as for sterilizing water supply and sewage, are hypochloride solutions, such as bleach liquor, which is usually made from bleaching powder or sodium hypochlorite, powerfully reactive substances. This is often stored in concrete tanks, which are liable to attack, causing loss of liquor through seepage. One of the more recent treatments to prevent such attack is application of chlorinated rubber to the inside of the tank. Typical of this method is that recommended by Detel Products, Ltd. Detel is chlorinated rubber dissolved in an organic solvent and applied to the surface with a brush.

The tenacious, non-inflammable and non-porous film formed possesses remarkable properties of resistance to many kinds of corrosive and deleterious influences, including not only acids and other substances in water, such as salt (as in sea water) and bleach liquor, but almost every known acid or alkali, dilute or concentrated. Any type of surface, apart from concrete, can also be treated in this way on most effective lines, including iron, steel and other metals, brick, asbestos, cement, plaster and wood.

In one establishment, as typical, a concrete tank used for bleach liquor was affected to such an extent that it lost several gallons per day through seepage. After being cleaned, however, it was given three coats of Detel " Red A," product containing inorganic red colouring material, and although this treatment was carried out about five years ago the tank is still entirely free from seepage.

There is also available for the protection of iron and steel against corrosion another variety known as " D.M.U.," which contains about 92 per cent. finely powdered zinc. This has the effect of giving anodic protection, so that the tendency is to attack the zinc and not the iron or steel.

In the establishment already mentioned great trouble used to be caused by severe corrosion of a cold-water pipe which passed through a hot and steamy atmosphere so that water continually condensed on the surface, representing ideal conditions for corrosion. The life of cold-water pipes under these conditions is about six months, but after several coats of " D.M.U." this pipe has so far remained unaffected after four years.

Further, for stopping leakages in tanks and similar apparatus the product is available as a soft paste and also as a thin flexible sheeting, while another modification will stand a temperature up to that of boiling water. In general chlorinated rubber, while possessing all the good points of rubber, has the additional important advantages of greater resistance to chemical action, and is almost completely fireproof.

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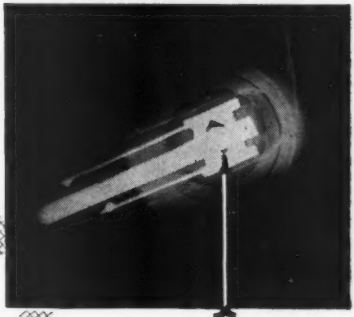
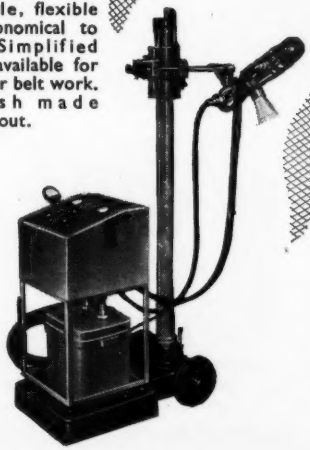


Radiograph of moulded assembly showing incorrect location of metal insert.



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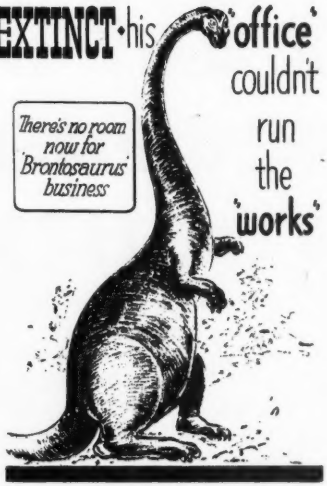

In primitive times sheer brute strength and massive bulk seemed all-sufficient to ensure the survival of the fittest. Time has proved, however, that all bulk and no forehead did not guarantee fitness.

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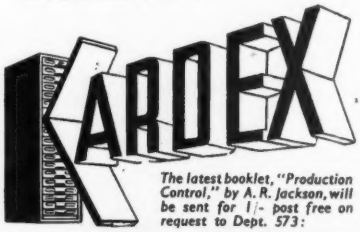

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PRODUCTION NEWS

Raw Materials, New Plant, Works Organization, Control Apparatus, Research, Personal and Trade Notes

EFFICIENT GAS FIRING.—For the firing of steam boilers it is often an economical proposition to use gas firing, say producer gas, coke oven gas, or even town gas, apart from the special circumstances when blast furnace gas is available. Of outstanding value for the purpose is the range of latest design " Gako " turbulent burners supplied by Liptak Furnace Arches Ltd., of London (68, Victoria Street, S.W.1), which are available in a considerable number of sizes and modifications, although the basic principles of the design are the same.

Essentially they consist of separate and independent valve control of the gas and air supply, which are also split up in the burner into a number of independent thin layers of streams, each of which is given a twisting or whirling motion by means of spiral guides or passages. The result is an extremely intimate mixing of the gas and the air, with rapid completion of the combustion, giving a short globular flame, with high CO_2 and little excess air. Another feature is that the operation in under low-pressure conditions, generally 2-4-in. w.g., which eliminates all " stratification," that is non-uniform furnace temperature, which is apt to be one of the inherent troubles of high-pressure burner operation.

Special features of all the designs are the simplicity and accessibility, with no moving parts of any kind, while all that is necessary is to open a hinged door for cleaning and full inspection without disturbing the burner casing and the pipe connections. Because of the design, resulting from extensive experience of a large number of installations, two gases also of different qualities can be burned separately or together, such as town gas, coke oven gas, producer gas, and blast furnace gas. Cold or preheated air can also be used, either at atmospheric pressure or slightly above, say up to 4-in. w.g., already mentioned, whilst it is often good policy to have the gas and air supply valve, when once adjusted, connected by linkwork so that for any given rate of gas passage the correct volume of air is always being used.

It cannot be too strongly emphasized that no one design of burner will give the best results for all furnace conditions, and the main advantage of " Gako " construction is the range of modifications available, one or other of which will give maximum efficiency for specific installations. In this connection the long experience of the firm is also particularly valuable.

Another important development is the introduction of automatic control equipment, including an integral electric motor supplying the low-pressure air which gives not only extremely efficient combustion of the gas but enables both the latter, as well as the air, to be automatically regulated without difficulty, varying the degree of opening of the gas supply valves and air damper. Automatic operation can be controlled by the temperature at any specific point in the furnace setting, and also in the case of steam boiler plant by the pressure.

MACHINERY, PLANT AND APPLIANCES (CONTROL) ORDERS.—The Machinery, Plant and Appliances (Control) (No. 3) Order 1942 (S.R. and O. 1942 No. 2,487, price 2d.), which came into force on December 9, 1942, replaces previous Orders and makes substantial amendments of, the additions to the Schedule of machinery, plant and appliances, the supply and acquisition, and in certain circumstances the use of which is already prohibited except under licence from the Board of Trade. To avoid possible contravention of the Order, manufacturers and prospective acquirers of machinery, plant and appliances should obtain copies of the Order from H.M. Stationery Office or through any bookseller, and acquaint themselves with its full provisions. Application forms for licences may be obtained from the Machinery Licences Division, Board of Trade, 1-6, Tavistock Square, London, W.C.1.

FIXED CAPACITORS—B.S.1082-1942.—A new British Standard Specification has recently been published for Fixed Capacitors —B.S.1082. This specification is based on technical information supplied by the British Electrical and Allied Research Association, which organization has carried out considerable experimental work with a view to revising and extending the scope of the 1926 edition of B.S.271.

The latter specification was limited in scope to the small capacitors used at that time in radio receivers, but the considerable extension of radio broadcasting in recent years and the parallel developments of other activities involving the use of fixed (i.e., non-variable) capacitors, clearly necessitated the drafting of a more comprehensive specification. As will be seen in Clause 2 of the present specification, it covers all fixed capacitors for general purposes whatever the nature of the electrodes and insulant. It is not, however, intended to apply to capacitors for specialized application.

Copies of this new British Standard may be obtained from the British Standards Institution, 28, Victoria Street, Westminster, S.W.1, price 2s. (2s. 3d. post free).

N.E. LONDON SUPERVISORS' DISCUSSION GROUP.—The opening meeting of the Winter-Spring Session of the above Group will be held at the South-West Essex Technical College, Walthamstow, on Tuesday, January 26, 1943, at 7 p.m. The following problem has been submitted for discussion:—" The Management of a Company engaged on War Production feels that its output could be improved with the present staff and plant. They have suggested that a Joint Production Committee, composed of workers and Management representatives, should be instituted to discuss means of increasing output by improving organization, etc. A meeting of all employees, who are predominantly Trades Unionists, rejected the Management's suggestion on the grounds that the desire for improved output was meant for the benefit of the Company rather than War Production. How can this attitude of mind and outlook be overcome? " All who are interested will be cordially welcomed. Tea may be obtained at the College from 6.30 p.m. as usual.

CARRIAGE PAID.—Traders are reminded that, as announced early in November, traffic by merchandise train must be sent " carriage paid " as from January 1 last. This means that the consignor must be responsible for paying carriage charges at the forwarding station but does not involve pre-payment if the consignor has an authorized credit account with the railway. The Order, entitled " Railways (Carriage Paid) Direction, 1942," S.R. and O. No. 2578, has now been made, and as soon as it has been printed copies may be obtained from H.M. Stationery Offices in the usual way. The requirement that goods should be sent " carriage paid " is necessary to save railway man-power and to enable the railways to deal with the growing volume of war traffic. At present, traffic by passenger train and about 75 per cent. of the consignments by merchandise train are sent " carriage paid." The Minister appreciates that the change-over to " carriage paid " in the case of the remaining portion of the traffic may in some cases cause difficulties to traders, as adjustments in their practice will be necessary. He asks all those concerned to do their utmost to ensure that the change-over is effected as smoothly as possible and so help further the war effort.

PRODUCTION AND ENGINEERING BULLETIN.—The December, 1942, issue of this valuable bulletin, issued by the Ministry of Labour, contains some interesting articles, among which are " Methods of Improving Arc Welded Production," " Office Aid to the Factory," " Principles of Turret Lathe Tooling," " Production Charts as Incentives," etc.

STEAM FOR PROCESS HEATING.—The Forum Publishing Company, 27a, Pembridge Villas, W.11, has just published the 2nd Edition of a booklet by A. H. Hayes, F.C.S. on the above subject. Its object is to place before the user of steam for heating processes in industry various information of practical value. In other words, it is designed primarily to give fundamental data in plain language, so that the steam user may increase considerably the efficiency of his plant by referring to the basic principles of steam heating and modifying or altering the operation of the plant accordingly. In this the author succeeds admirably and has incorporated some excellent examples of practical application, such as the layout of steam circulating apparatus for textile works, oil tankers, chemical plant, etc. There are numerous illustrations, diagrams and charts that simplify the examples. Price 8s. 6d. post free.

Personal

Mr. H. H. Lusty, advertising manager of Bakelite, Ltd., has become a Committee member of the Publicity Club of London.

Friends will be pleased to hear that **Mr. Paul Smith,** who was assistant Editor of " Plastics " from 1937 to the outbreak of war and who early received a commission in the South Staffordshire Regiment, has been promoted to the rank of captain.

Resinoids and Other Plastics as Film Formers

By B. J. BRAJNIKOFF,
Consulting Electrical Engineer

XV.—High Polymers as Colloidal Systems

THE clarification of the problems relating to the mechanism of colloidal solubility and solvation of high molecular compounds is of great significance both from theoretical and practical standpoints, since such questions as, for example, the preparation of the resinous solutions of suitable properties and concentration, the methods of their adequate stabilization, etc., are of immediate concern to the technology of surface coatings, the formation of films, monofils and fibres, adhesives, impregnants and other compositions.

The Structure and Stability of Colloidal Particles

Present-day colloidal chemistry has no unified, consistent and generally recognized theory of the structure of colloidal particles and their stability. Notwithstanding the existence of such works as those of von Weinmarn's "Grundzüge der disperoid Chemie," Duclaux's "Colloids," and other treatises, which form the basis of modern hypotheses, yet we are still very far from the quantitative interpretation of these phenomena.

We know that each colloidal particle has necessarily on its surface either molecules or ions of a substance, which is taking part in its formation (the stabilizer); we also know that a colloidal particle produced in an aqueous medium (and in some organic solvents) carries on its surface an electric charge, whilst for the colloidal particles of one and the same chemical constitution the sign of this charge may be either positive or negative, depending upon the polarity of an ion of the stabilizer adsorbed by the particle. It is precisely here, when we are confronted with the selective adsorption of ions of stabilizer that we are at a loss to find an explanation of this selectivity. We do not know why the particle, under one set of conditions, adsorbs one kind of ion, and, under other conditions, a different kind of ion. We record an observed fact and describe the results of experiment, but we do not reach the root cause that governs the mechanism of ionic selectivity, unless the expression "adsorbed" that or another ion is regarded as explanatory.

The problem of the structure of particles of high molecular weight products, forming, in their dissolved state, mainly lyophile systems, is reducible to the investigation of their molecular or micellar structure, and since the particles in solution exist in definite connection with the molecules of solvent, it follows that the study of the nature of such an interaction, evidently, can furnish indications and, ultimately, an explanation of the solvation process and kindred phenomena.

How divergent are the hypotheses arrived at by applying different methods of approach to the above problem may be illustrated by the views on lyophile colloids, as typified by the acetylcellulose sols of the three leading schools of thought. The first and the earliest theory, belonging to Hess, holds that the so-called high-molecular compounds are built up from very small molecules, combined with one another by the forces of association, where the bond is so weak that it is broken down during the solution process. Thus, according to Hess, cellulose represents the product of association of discrete glucose radicals united not in the direction of the principal but of the secondary valencies.

The second theory, that of Meyer and Mark, on the contrary, depicts the cellu-

lose particle as built in the micellar fashion, where the micelle is regarded as consisting of 40 to 60 molecules bonded to one another by the secondary valence forces, and containing from 30 to 40 glucose radicals.

Lastly, the third theory, as propounded by Staudinger, considers the molecular structure of such combinations as composed of the molecules possessing a giant size and chainlike shape.

In accordance with the aforesaid hypotheses, the question of solvation of particles of high-molecular compounds is interpreted also in a different manner. Thus, Staudinger, on the basis of Langmuir's adsorption theory, holds that the solvation layer on the colloidal particle cannot exceed the dimensions of one molecular diameter, and on these grounds ignores the solvation aspect in his viscosimetric studies, completely disregarding a long-established and experimentally checked notion of the "diffusion" layer.

In contradistinction to the foregoing opinion, Meyer and Mark accept the existence of polymolecular solvation layers, and, on the basis of the miscellar architecture of particles, they, in unison with Ostwald's views, consider not only chemical solvation, but also a purely geometrical connection of the solvent with the colloidal particle (immobilization).

Sol Formation and Coagulation of Colloids

Despite numerous difficulties inherent to the studying of the colloidal systems as emphasized above, the recent years have been marked by definite progress in bringing to light certain chemical and physical factors conditioning their behaviour. The mechanism of sol formation and coagulation of lyophobe colloids, in their essentials, has been elucidated in such a measure that at present we are in a position not only to make these sols of sufficient concentration, but even to predict their many properties; for instance, their charge, stability, chemical performance, etc. All this has become possible owing to systematic researches of Duclot, von Weinmarn, Pauli and others. As is known, these works have proved to be so fruitful, due mainly to the fact that, by contrast with the older theories, which regard colloidal particles as existing in an isolation from dispersion medium of a system (sols), the above investigators for the first time directed their attention to the problem of the relation and connection between the dispersed phase and the dispersion medium. The micellar concept, as a qualitatively new system, the notion of solvation agency, have been so fertile that now we have no doubts that the existence, in the form of a sol, of the colloidal particle nucleus, inert to the dispersion medium, is due to ions of the solvation process, which thus conditions the connection between nucleus and dispersion medium. Strictly speaking, this inertness of the nucleus to the dispersion medium has been the primary factor that induced workers to inquire into the structural aspects of colloidal particles, since it is exactly this inertness that handicapped the understanding of a number of characteristic features of colloidal particles.

In this respect particularly valuable were the views of von Weinmarn, who in his later works was able to evolve a comprehensive theory, according to which the molecules of all substances in any state of aggregation possess vectorial properties. Recent spectographic studies of matter, with the aid of X-rays, have confirmed this theory, both in respect to "colloidal" particles, whose crystalline structure was obvious earlier (e.g., alumina, silica, etc.), and also to such bodies, the crystallinity of which seemed to be less probable (viz., gelatine, etc.).

Lyophile Colloids

As to the problem of the lyophile sols, its position was different. With regard to this group of colloids, no pressing need was felt either concerning the structure of their particles or the question of inertness of their particles to a dispersion medium; on the contrary, the connection of such particles with dispersion medium appeared to be quite clear, for the reasons

that lyophile colloids derived their very name on account of their strongly pronounced interaction with a dispersion medium; the presence of hydro or other generally lyophile groups in a particle thus characterized their natural connection with the molecules of solvent. But in such an event the lyophiles acquire the properties of true solutions, and should possess a normal true solubility. Indeed, it is, mainly, under this angle that such systems were viewed by a number of investigators, who regarded lyophile sols either as identical with the true solutions, reducing the difference between them to a mere distinction of the particle size (Sörensen, Loeb), or considered them as super-saturated systems (Bradford and others). Although such views are still widely maintained nowadays, nevertheless they are beset with a series of difficulties due to the fact that lyophiles, under a close examination, revealed certain features, which remind us of the properties of lyophobes.

Kruyt,[152] in studying the electrical characteristics of lyophiles and their stability, has arrived at the conclusion that lyophiles are hydrated lyophobes, i.e., their nucleus is just as lyophobe and inert to the dispersion medium as that of most of inorganic colloids, and the connection with solvent is also realized through the agency of the solvation, whose functions are performed by the molecules of the same substance situated at the surface. Moreover, the solubility itself of these colloids was found to be far from anomalous, being related, fundamentally, both to the weight of the material and to the volume of a solvent.

It is these observations that prompted several workers to revise the entire question of the structure of particles of lyophile sols, and, consequently, the mechanism of their formation. Ostwald[193] was one of the first investigators to grapple with the above problem in a systematic manner. Although his efforts so far have not proved the identity of structure of lyophiles with that of lyophobes, there are increasing indications of this in Ostwald's recent researches, which emphasized not only the complexity of the phenomena of lyophiles, but clearly manifested a definite individuality in their behaviour.

The Types of Lyophile Solubility

This circumstance induced Ostwald himself to abandon the idea of developing a generalized hypothesis for the so-called "precipitation rule" and to consider instead at least four basic types of interactions:—(1) adsorption peptization, the case, when the solubility, just like that with lyophobes, occurs clearly on account of adsorption of some substance by the surface of particles; (2) dissolution peptization, i.e., the solubility on account of formation of a new chemical compound, which serves as a peptization agent; (3) peptization of the swelling bodies, when the solubility takes place due to elevation of the temperature or the addition of electrolytes, which increase hydration and promote the disruption of a micelle into its separate elements; and, finally, (4) spontaneous colloidal solubility, the solubility of polydispersion, polysolvation particles, of substances built of a mixture of the products of various degrees of the polymerization, as well as the peptization of gels, with the simultaneous hydrolysis or the chemical action of solvent.

A general and dominating feature in all the four types is the recognition of the absence of the direct solubility; in all cases the latter is promoted and conditioned by an extraneous substance. Of special interest is the last (the fourth) type, mainly because it is particularly close to lyophiles. It has been known for a long time that some workers held the view, according to which high molecular organic combinations, as, for instance, gelatine, are a mixture of the products of different degrees of polymerization; in addition to gelatine, which was shown to consist of several separate fractions, including the fraction of high molecular weight, it has also been found that similarly, for example, acetyl- and nitrocellulose, and other high polymers, contain several fractions of various degrees of polymerization, which have been duly

isolated. One of the most interesting conclusions from the above is the separation of a fraction of high molecular weight, which is difficultly soluble, or practically insoluble in a given solvent.

In the light of these investigations the problem of the structure of lyophile sols acquires a special significance, since the so-called insoluble fraction is separated out from solution, where it was in a dissolved state. This circumstance gives ground for the natural inquiry (as expressed by Ostwald, Kruyt, and others) whether or not this high molecular fraction exists in the dissolved condition on account of the low molecular weight fraction, which acts as a peptization agent.

Hence, it may be inferred that both the process of the colloidal solubility of the lyophiles (that is, the problem of a normal or induced solubility) and the closely related mechanism of solvation of nuclei and the surface layer of particles, are still very far from clear.

Colloidal Solutions

In this respect, of special interest are the so-called colloidal solutions, occupying a position intermediate between the emulsions and true solutions; whereas the true solutions consist of the uniform distribution of single molecules or electrically charged atoms and ions in a solvent (with the solute particles of the order of 10^{-7} cm.), the colloidal solutions are formed by a statistically uniform distribution of clusters of similar molecules (or molecular complexes with the diameter from 10^{-3} to 10^{-5} cm.) held in suspension by the energy derived from surface tension. A very characteristic property of the colloidal solutions is their precipitation or coagulation, that is, the liberation of a dissolved dispersoid from sol, owing to aggregation of micelles into larger particles; the precipitation is caused either by the change of physical conditions, in which hydrosal is finding itself, or by adding a foreign matter to the sol. The passing of sol into gel does not proceed with equal ease and speed by all hydrosols. The products of coagulation may be either irreversible gels, i.e., those that are not capable of giving sol again under the action of solvent, or reversible gels.

Among the physical conditions, the alteration of which leads to the precipitation of the sol, should be mentioned the variation of the thermal regime—from the freezing point to the high temperature levels. The introduction of a small quantity of foreign body has no effect upon the ease of coagulation—in this way behave, for example, organic compounds, which do not ionize in aqueous solution.

The immediate cause of coagulation produced by a reagent added to sol is the decrease in the degree of the ionization of a micelle due to both the factor of purely chemical nature (the change in the micellar composition) and, in consequence, to adsorption taking place on the surface of the micelle. If the added body is an electrolyte, its ions can act in different ways—they may yield, in conjunction with the granules, an insoluble product forming the coagulum; they also can, should they belong to a class already contained in the sol, effect the decrease of solubility of a dispersoid, which in colloidal solutions plays the same role as in the solutions of crystalloids, etc. The greatest effect is produced by polyvalent ions, which carry a large electrical charge; the greater the magnitude of micelles, the easier proceeds coagulation—a factor of importance in film-forming compositions, particularly of the synthetic latex class.

The Theory of Synaeresis

Thus colloidal chemistry knows two extreme kinds of changes: (1) The reversible processes, in which the initial state of a system, varied in time, may be restored, and (2) the irreversible processes. Between these two types of variations there may also occur a third, or intermediate, type with partially reversible characteristics, which are of very frequent occurrence and produce the so-called hysteresis phenomena.

(a) The reversible changes are usually observed in chemical compounds, which are stable to thermal and other influences. As a result of aqueous solution, a two-

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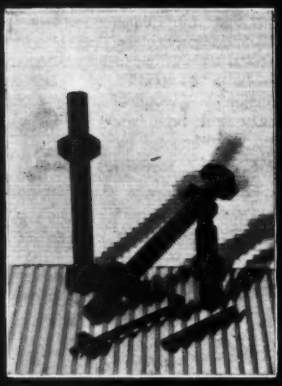

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phase system is formed (hydrosol), wherein one of the phases, due to forces of association, contains the colloidal particles of the solute, and the other (the normal phase) comprises its molecules. Under certain quite definite conditions, both phases are in a state of equilibrium with one another:

Molecules $\rightleftharpoons$ colloidal particles.

Observing the variations of such systems in time, we will find the following process: Sol $\rightleftharpoons$ gel $\rightleftharpoons$ synaeresis, i.e., these changes are entirely reversible. The chemical composition of particles of such colloids, throughout the period of these transformations as well as during the thermal treatment, no matter how intensive and prolonged it may be, remains unaltered, nor does their associative power conditioned by the presence of the supplementary unsaturated bonds vary.

(b) Incompletely reversible variations very often occur with such materials as gelatine, starch and other substances. The chemical constitution of these is not sufficiently established, but it is known that some are a mixture of several compounds, as in the case of starch.

By the process of solution in water these bodies also form the two-phase systems, where both the phases are in equilibrium: Molecules $\rightleftharpoons$ colloidal particles, i.e., these colloids also have quite a definite true solubility in water, although their molecules may be large and approach colloidal dimensions.

In the event of such systems undergoing the transformation: Sol $\rightleftharpoons$ gel $\rightleftharpoons$ synaeresis, there can be no assurance that the structure of their molecules, and, therefore, of the colloidal particles formed by them, will remain constant throughout the length of these variations. Having regard to what has been stated above, it is more logical to expect the effect of the reverse nature. Hence it must be clear that in such systems we study the inter-actions, is a greater or lesser degree, of the chemically changing particles with one another.

(c) The irreversible phenomena may give rise to most diverse processes, which fall under the two principal headings: (i) Chemical reaction, when as a result of chemical transformations of colloid, a new substance is produced, possessing distinctly different characteristics; and (ii) physical process—the crystallization of particles, the orientation of which is braked.

In such cases the above-indicated transitions are irreversible: Sol $\rightarrow$ gel $\rightarrow$ synaeresis, and they are evoked not only through the approach and proximity of colloidal particles, but also because of their crystallization, which, depending on conditions, may proceed with various speed and intensity. The result of such phenomena is that in such a case we are also studying two concurrent, parallel processes, namely, the approach of the unchanged particles and that of modified ones, i.e., the crystallized elements.

Secondary Phenomena

Colloidal processes are often accompanied by the alterations of the molecules in the chemical sense. For instance, viscose undergoes the irreversible splitting off into cellulose and a number of simple inorganic combinations. In such an event, as was pointed out before, the colloidal processes are complicated by secondary phenomena, and are difficult to understand without taking into account these corollary aspects.

As a rule, the higher the concentration of a system, the shorter the distance between particles, the sooner takes place such a formation of structures, i.e., gelation. Beginning from the moment of gelation, the body of gel undergoes continuous changes—by means of the ultramicroscope its separation into two phases —micro-synaeresis may be seen.

If a colloidal particle is strongly charged, the interaction between the forces of molecular attraction and the forces of electrical repulsion is intensified, and the general effect will depend upon the relative magnitude of these forces. Should the electrical repellent forces greatly exceed the forces of attraction, no further changes will then occur in the

system; if the attractive forces are superior to the repulsive forces, a mutual approach takes place between colloidal particles until both kinds of operating forces attain equilibrium.

Should, finally, the colloidal particles carry no electric charge, they will approach one another and will aggregate. Depending on the intensity of the forces acting between the colloidal particles, the hydrated particles can approach each other either with the deformation of aqueous envelopes, or merely form contact with them. In the first case there is no ground for supposing that it will necessarily cause dehydration, for this may only promote the weakening of bonds between the water molecules due to displacement of them.

The Solubility of High Molecular Compounds

Notwithstanding the fact that solutions of substances of high molecular weight possess a large number of characteristic properties, they are usually referred to as colloidal solutions, without taking into account their peculiar features. This is due to an attempt to apply also in this case a widely used classification of dispersed systems according to size of particles. This tendency, when materials of high molecular weight are considered as typical colloids, has led to the circumstance that a series of regularities found in exploring the lyophile colloids, by analogy, was transferred to solutions of high molecular compounds.

As has been stated previously, the foundation of high polymeric chemistry dates back just to the first decade of the current century, since when has commenced a systematic study of high molecular products: at that time the lyophobe colloids had already been well investigated and the fundamentals of such colloidal systems have now been ascertained. Naturally, in studying the high molecular substances as one of the groups of colloids, the scientific workers employed a number of basic concepts evolved from researches on lyophobe colloids and extended them subsequently to the other groups of colloids. However, a more detailed examination of high polymeric materials, particularly of late, leads to the conclusion of the impossibility, in many cases, of such a transference to them of the notions established in relation to lyophobe systems.

Characteristics of Solutions of High Polymers

It may be accepted that the classification of the solutions given by Ostwald, and based upon the different dimensions of solute particles, is now inadequate. Doubtless all the systems containing particles of great size, irrespective of their chemical nature, will possess a number of common properties, and may be unified under a general expression "colloids," only in this meaning of the term. However, most of the properties of the colloids, viz., adsorption, the phenomena of peptization and coagulation, optical characteristics, etc., result from the microheterogeneity of colloidal solutions and the fact that colloidal particles are aggregates consisting of greater or lesser numbers of molecules and possessing boundary surfaces. As the colloidal systems proper, in the strict sense of the term, the majority of investigators include exactly those systems in which particles represent similar aggregates, in contradistinction to true solutions containing a substance (solute) in the molecular degree of dispersion. Furthermore, the dimensions of the molecules of a truly dissolved body possessing great molecular weight (viz., dyestuffs) can have larger sizes than the particles of finely dispersed colloids, as, for instance, those of gold or iron oxide (of the order of 15 to 20 Angstrom units). Finally, in the case of high molecular compounds, we encounter the molecular weight of several tens of thousands and even hundreds of thousands, which, in accordance with Ostwald's terminology, should be referred to as colloidal particles. At the same time, these high molecular weight products may be present in solution in the form of single molecules. This raises the question whether we should regard the solutions of substances with

high molecular weight as colloidal solutions, or as true solutions. This question is one of the basic aspects in this field, although some investigators, e.g., Kruyt,[194] in their treatment of the colloidal processes, deliberately refrain from discussing this problem.

The Stability of Systems

There can be no doubt that particles of lyophobe colloids are aggregates consisting of a great number of molecules, in most cases being the aggregates of crystalline nature. Such systems represent the systems which, thermodynamically, are unstable, and the attainment by them of a state of equilibrium would correspond to transformation of the entire colloidally dispersed substance into monocrystal. The stability of these systems is determined by the existence on their surface of adsorption layers, which are formed through adsorption of electrolytes, and in some instances by the presence of the solvation layer. In this case, in the process of interaction with the dispersion medium, is involved not the whole body of colloid, but only that part which is situated on the surface. The rest of the substance, constituting a colloidal particle, remains totally unaltered under any variation in the composition of the dispersion medium, and in its structure and properties is analogous to any small portion of the same material in the microscopic state. The presence of such crystals in lyophobe systems has been convincingly proved by the researches of Weiser.[195]

If solutions of high molecular weight compounds were to form the similar systems, then, doubtless, they should be included among the true colloidal systems. Indeed, a number of workers[196] consider that solutions of high molecular products possess those features of the colloidal solutions, which were enumerated above, and on these grounds class them as colloidal solutions that are microheterogeneous and unstable in a thermodynamic sense.

As a basic proof of microheterogeneity is usually stressed inapplicability of the phase rule to the processes of solution and precipitation of high molecular compounds, which in the most generalized manner has been formulated by Ostwald's " precipitation rule." Another reason put forward in support of microheterogeneity is the phenomenon of " ageing " and, in general, the presence of irreversible processes (hysteresis phenomena during solution and precipitation). As an indirect proof of the existence of microheterogeneity of solutions of high molecular compounds, is the absence of reproducibility of the results obtained by various authors in studying solutions of high polymeric substances, and the dependence of the properties of these solutions upon the method of their production.

In the opinion of Karguin and his co-workers at the Moscow Synthetic Fibres Institute, most of the researches on the applicability of the phase rule to the solution processes suffer from two drawbacks. First, high molecular weight materials are always heterogeneous in so far as the particle size is concerned, in consequence of which the systems—high polymeric substance/solvent—are not binary but polycomponent. This circumstance has been disregarded by the majority of authors. Secondly, the period of time required for attaining the conditions of stability in such systems is very great, and for this reason it is always necessary to check whether or not the state of equilibrium has been reached in a given experiment.

The Applicability of Phase Rule

By meeting the conditions of homogeneity and of attaining equilibrium some workers have succeeded in a number of cases in proving the applicability of the phase rule to the systems: high polymeric material/solvent. The first to achieve this was Sörensen,[197] who performed the process by using crystalline albumin in an aqueous solution of sodium sulphate. Later work of McBain and Jameson[198] has also demonstrated the feasibility of applying the rule of phases to the solution of egg white. Recently Papkoff, Karguin and Rogovin[199] have

found that phase is also applicable to the systems: acetylcellulose/solvent.

The applicability of the phase rule testifies, first of all, to the fact of the absence of microheterogeneity of the above-mentioned systems, i.e., the absence of the boundary surface between a solvent and solute. As a consequence of this are the complete reversibility of such systems and their thermodynamic stability, which circumstances fundamentally distinguish these systems from typical colloids. Due to this factor, the systems : high molecular substance/solvent, in their properties are similar to normal liquid systems (a mixture of liquids), and, therefore, it is more appropriate to include them into the latter class, and not in the colloidal systems analogous to hydrophobe colloids.

Distinction Between Solutions of High and Low Molecular Weight Products

In considering solutions of high molecular weight compounds as true solutions, we should first of all pay attention to those peculiar features which differentiate them from solutions of materials with low molecular weight.

Special significance attaches to a very characteristic action of small quantities of foreign substances upon the properties of the solutions of high molecular weight compounds, as well as of all solutions containing particles of great weight, regardless of the fact that they are single molecules or molecular aggregates. This is shown by the action of apparently negligible amounts of extraneous agent, which may alter the properties of the solutions, viz., the solubility, viscosity, etc., in the most powerful manner. These quantities are small in relation to the general amount by weight of material, but if we will take into account the high molecular weight of a substance we will see that small weight proportions correspond to adequately high molecular ratios. For example, in the case of acetylcellulose, with molecular weight 40,000, the introduction of 0.14 per cent. of calcium oxide corresponds to equimolecular proportion. Each large molecule (or particle) forms one molecular-kinetic unit, irrespective of its molecular weight, and, therefore, in the event even of single bond arising, whose energy would appreciably exceed an average value of the molecular-kinetic energy, this conditon is sufficient in order to unite the two molecules, regardless of their molecular weight, into a single aggregate.

For this reason, such properties as, for example, viscosity, may depend upon minute and usually neglected admixtures, the amounts of which in any operation (viz., repeated precipitation and the like) easily vary; this creates an impression of irreproducibility of properties.

Another peculiarity of the systems is the slowness of the processes connected with aggregation and disaggregation of large molecules. Such processes, which take place in a homogeneous medium (solution) have almost no heat of activation, and are distinguished by characteristic very low values of the steric factor, owing to the drastically accentuated asymmetry of molecules of high polymeric materials.

Although the rate of progress of these processes which do not reach their completion may be extremely slow, a true equilibrium is always established after a certain interval of time. This, as has already been indicated by Sörensen,[197] may prove a very lengthy period, a fact overlooked in many experiments.

Colloidal Activation, Equilibrium and Longevity

The processes in heterogeneous systems (viz., the solution, the establishment of the equilibrium between the two phases, and, in general, processes connected with the passage of molecules through some boundary surface) may change with increased energy of activation. This pecularity is also characteristic to all systems, whose molecules or particles have a great weight. Each molecule (or particle), irrespective of its molecular weight (in the first approximation) possesses one and the same average store of molecular-kinetic energy, but different amount of polar groups, due to

which the activated barriers for separate groups will be integrated. Thus, even low values of activation energy per mol of the polar groups will yield a sum total of many calories. At such heats of activation and at ordinary temperatures, the processes usually do not proceed at all and, therefore, we can easily conceive the occurrence of meta-stable conditions during the solution phenomena (e.g., gelatine in water) or distribution between the two phases (viz., polyethyleneoxide in Schulz's[200] experiments).

Naturally, there is every justification to regard the solutions of high molecular compounds as real solutions, in which molecules can interact with one another, giving rise to the formation of associated groups of one or another kind. The existence of such groups is, in general, very characteristic of real liquids, wherein these groups can be created and decomposed, and their very existence has a purely statistical nature. Thus, it is of importance to find out in what measure the presence of such groups affects the establishment of true equilibrium during variations in the composition of a solvent medium. Obviously, this process, progressing in time (a period of relaxation of the system), will be determined by the mean time of "life" of such groups, and the kinetics of attaining an equilibrium will be conditioned by the same set of values. If an average interval of "life" of such a grouping is infinitely great, there, generally, will be no equilibrium, and such an aggregate will form a particle, whose constitution, number and mutual arrangement of molecules will not vary with the changes in the composition of media.

It is legitimate, then, to ascribe to such particles the properties of phase and to the whole system the characteristics of a thermodynamically unstable colloidal solution.

In those cases an average period of "life" of groups of the associated molecules is very small, the state of equilibrium will, practically, be established instantaneously, and the properties of systems will correspondingly approach those of an ideal liquid or solution. For the systems with a great but a finite period of relaxation, the equilibrium is being established at a slow rate. In this event, with the change of composition of the system, we should take into account the circumstance that, in the course of an interval of lesser duration than the relaxation period, there prevails an unbalanced system.

In contradistinction to liquids, solutions can change not only average longevity of the associated groups but also their constitution, for they may be composed from the solvated molecules. In this case, with the alteration of the constitution of a solvent, the velocity of the solvation and desolvation, which are determined by the diffusion speed of the liquid and by the rapidity of relaxation of the solvated envelopes, will considerably exceed the rate of the formation and disruption of the groups themselves. Thus, with the change in composition of a medium, the constitution of the associated groups will vary, practically instantaneously, and the alterations of the groups connected with the processes of aggregation or disaggregation of large molecules will proceed appreciably slower. This peculiarity distinguishes the solutions of high molecular products from such thermodynamically stable systems as paints, soaps, metals, etc.

Deductions

The above-described concepts of the nature of solutions of high molecular compounds may be summed up as follow: The solutions of high molecular materials form monophase, thermodynamically stable systems, which are true solutions of the substances with great molecular weight.

Separate molecules of the solute can associate with one another in a fashion similar to that which takes place in true liquids and solutions. The formation and disruption of such groupings occur in a reversible manner, and their very existence has a purely statistical character. The peculiar features of such systems are the lengthy periods of relaxa-

tion, consequential to a great molecular weight and to the asymmetry of molecules. As a result of this, the time required for the establishment of equilibrium is invariably long, particularly in the event when the molecules have to move through boundary surfaces (solution, distribution between two phases), and when the length of an experiment is shorter than the time required for attaining equilibrium; in all such cases we are dealing with unbalanced systems. This circumstance has not been taken into consideration by a number of workers who have examined irreversible processes, with the result that they were thus induced to regard these systems as unbalanced and microheterogeneous.

It should also be noted that high molecular compounds are almost always a mixture of polymer-homologues with different molecular weight and may be considered as a single component only with the proviso that they have been thoroughly purified prior to use.

If the colloidal solutions be interpreted as solutions that comprise any particles with a great molecular or particle weight, we may also include in this class the solutions of high molecular products.

However, account should be taken of the fact that the colloidal solutions in this meaning of the term are divisible into the two groups: (i) The microheterogeneous systems, and (ii) the true solutions of substances with a high molecular weight. Therefore, the extension of the regularities which are peculiar to any one group to an entire class of solutions is permissible only in those cases when this is connected with the common property, a great molecular weight.

(To be continued)

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FOR THE CAR BODY

(Continued from p. 8)

An alternative arrangement, utilizing steel box-section side members and a pressed-steel floor, is shown in Fig. 5, whilst details of the dashboard and toeboard are given in Fig. 6.

The doors would consist of bent wood frames approximately $\frac{5}{8}$ in. square, over which would be cemented moulded plywood panels. The door beading on the inside could conveniently be made from an extruded section in phenol-formaldehyde or cellulose acetate material. No sound-deadening packing would be necessary owing to the high damping properties of the wood. A suitable arrangement for the door is shown in Fig. 7.

General

Whatever may be the virtues of plastics as materials for car body construction, it would appear that under the existing conditions they could not hope to compete with the normal pressed-steel body. Nevertheless, it would appear less of a problem to make an economic proposition of the use of moulded plywood. Claims have been made by the advocates of the moulded-plastic type of body that no painting would be required, but in view of the fact that phenolic plastics, which are obtainable only in dark colours, are almost certain to be used it appears likely that some painting would be necessary. In his development of the plastic body Ford has found it advisable to finish his body in the conventional manner. With plywood construction, painting would most definitely be required, not only from the point of view of colour, but also as a protection against the ingress of moisture into the veneers.

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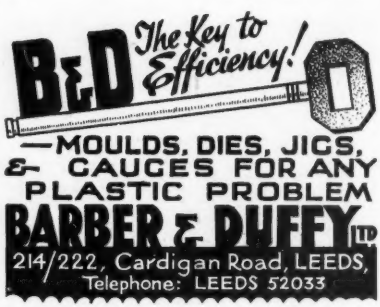
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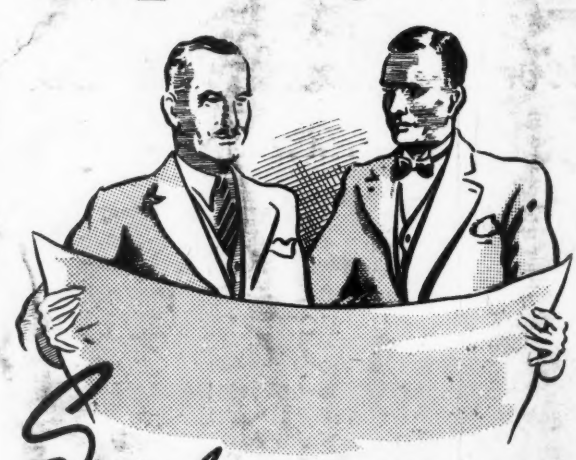

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